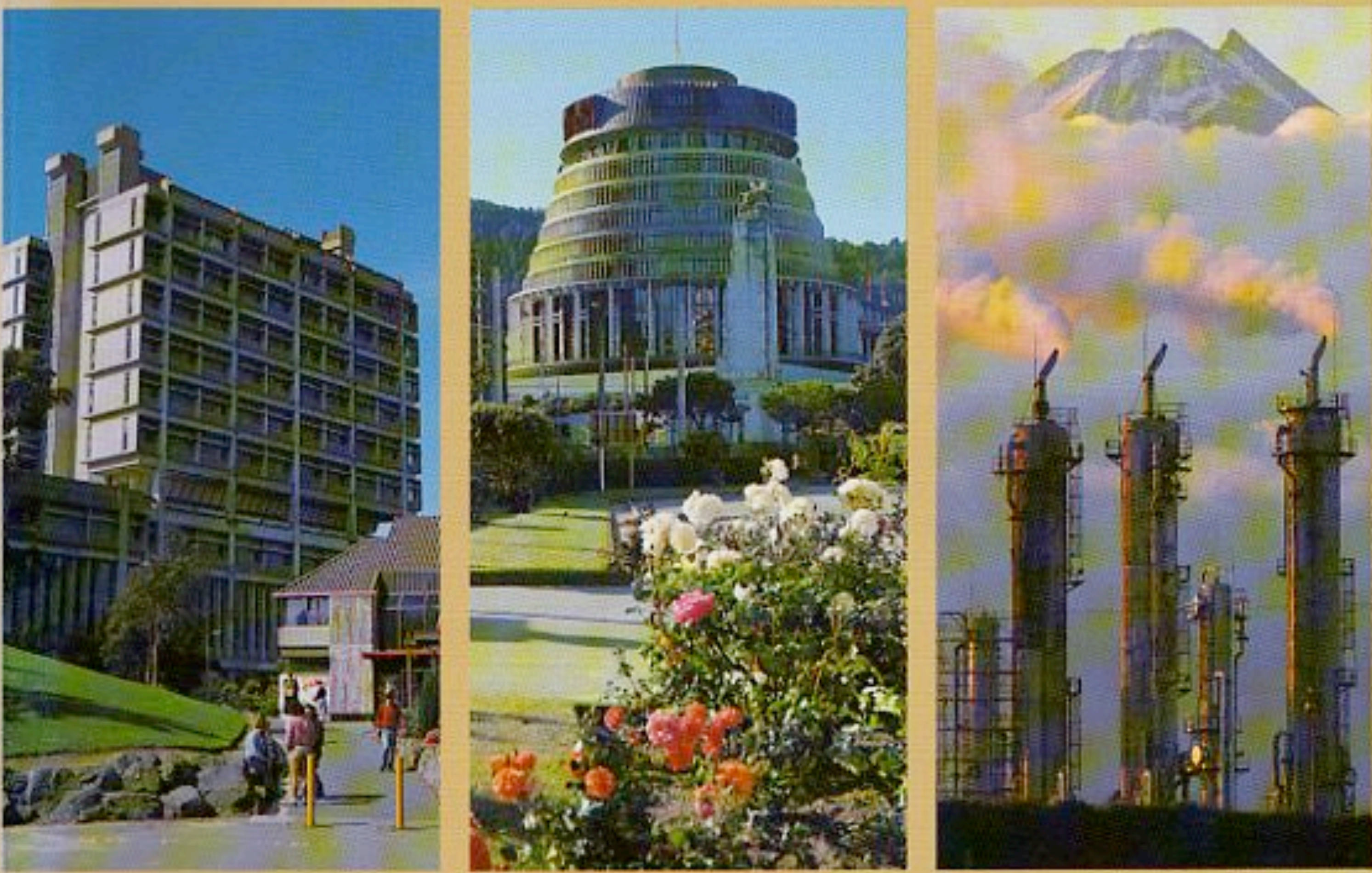
Centre for Advanced Engineering
University of Canterbury

STATE • INDUSTRY • UNIVERSITY LINKAGES

Encouraging better collaboration between Research Institutions and Industry



A Lecture and Seminar presented at the University of Canterbury on 9 July 1992 by

Eur Ing Professor
GORDON R WRAY
Ph.D. D.Sc. F.Eng. F.R.S.
Engineering Design Institute
Loughborough University of Technology

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August 1993

ISBN 0-9598002-8-X

COVER

Images of State, University and Industry - but what are the linkages between them?

Photographs : University of Canterbury Library (left), AV Photograhic Department, University of Canterbury; the Beehive, Parliament Buildings, Wellington (centre) and the Kapuni Gas Field (right), Warren Jacobs Photography, Christchurch

PRINTING

The Printery, University of Canterbury

NOTE AND DISCLAIMER

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Opinions expressed are those of the Seminar speakers and do not necessarily reflect the views of the Centre for Advanced Engineering.

Centre for Advanced Engineering

Establishment

The Centre for Advanced Engineering was founded in May 1987 to mark the centenary of the School of Engineering at the University of Canterbury. It was established by means of an appeal fund launched in conjunction with the centennial celebrations. To date approximately $2.4 million has been raised, contributed by 150 corporate donors and 650 individual donors. The earnings from this capital sum are used to run the Centre and fund its activities.

Objective

The objective of the Centre is to enhance engineering knowledge within New Zealand in identified areas judged to be of national importance and to engage in technology transfer of the latest research information available from overseas. The Centre is not concerned with basic engineering research, but with the application of research findings to engineering problems.

The objective is achieved for each major project undertaken by bringing together a selected group of practising and research engineers and experts in the particular field from both New Zealand and overseas to:

- consolidate existing knowledge
- study advanced techniques
- develop approaches to particular problems in engineering and technology
- promote excellence in engineering
- disseminate findings through documentation and public seminars

A unique forum for co-operation among industry, the engineering profession and university research engineers is thus provided.

Function

The Centre is controlled by a Board of Directors comprising representatives from industry, the engineering profession and the University of Canterbury. Chairman of the Board is Mr Peter Menzies of Auckland.

The Board selects the title for each project undertaken by the Centre and approves the level of funding. A Steering Committee is then appointed, initially to carry out detailed planning for the project and then to provide overall direction. The Steering Committee appoints Task Group Leaders and a Project Manager.

Detailed work on the project is carried out on a voluntary basis by the members appointed to each Task Group. The Centre arranges to bring to New Zealand, at the appropriate time, several Visiting Fellows to work with members of the Task Groups, bringing to the project the latest available information from overseas.

The Centre also undertakes smaller projects, such as the one described in this report, on engineering subjects of current concern, and arranges lectures and seminars on appropriate topics as the occasion arises.

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Eur. Ing. **Professor Gordon R. Wray**, FRS, FEng, BSc, MScTech, PhD (Manchester), DSc (Loughborough), CEng, FIMechE, CText, FTI, AMCST, FRSA, Hon MIED, was appointed Royal Academy of Engineering Professor in the Principles of Engineering Design at Loughborough University of Technology from August 1988. This multi-disciplinary professorial Chair, the first of its kind, was created through the initiative and support of the Royal Academy of Engineering, Britain's national academy of elected and distinguished engineers, in recognition of the increasing importance of engineering design as a unifying theme across all engineering disciplines. Professor Wray was previously Professor and Head of the Department of Mechanical Engineering at Loughborough.

Professor Wray is also the founding Director of the University's Engineering Design Institute, which was established as a centre of excellence for teaching the principles of engineering design to undergraduates, postgraduates, practising engineers and school teachers. The Institute also conducts interdisciplinary research in design across all sections of the university and, wherever possible, with industrial participation. It was recently awarded a grant from the Wolfson Foundation for new engineering design research laboratories.

At the age of 15 Gordon Wray was an engineering apprentice with Lancashire companies before becoming an engineering draughtsman. He then studied part-time at Bolton Technical College for Ordinary and Higher National Certificates in Mechanical Engineering and GIMechE. In 1949, he entered Manchester University as a Sir Walter Preston scholar and graduated with BScTech (Hons) to become a development engineer with Platt Brothers Limited. He lectured in Mechanical Engineering at Bolton Technical College from 1954 and became Lecturer in Textile Engineering at the University of Manchester Institute of Science and Technology (UMIST) in 1955, where he gained MScTech and PhD degrees as a member of staff.

Since being appointed as Reader in Mechanical Engineering in 1966 at the then newly-created Loughborough University of Technology, Dr Wray has been a forerunner at the University. In 1970, he was honoured by being the recipient of one of the first personal chairs awarded by the University, in recognition of his combined expertise in Mechanical Engineering and Textile Technology. In 1978 he became the first engineering staff member to graduate as Doctor of Science of the University.

Professor Wray is an internationally recognised authority on the design of high-speed and automatic machinery, being the author of numerous publications, having lectured world-wide and administered international projects. He also founded a large team at Loughborough concerned with the invention, research, design and development of such machinery, some of which has been widely exported. In 1975 he received the James Clayton Prize, the premier award of the Institution of Mechanical Engineers for 'outstanding innovation'. This was the third time Professor Wray had won an Institution Prize, having been awarded the Viscount Weir Prize in 1959 and the Water Arbitration Prize in 1972.

In 1986 Professor Wray was awarded the great distinction of being elected a Fellow of the Royal Society. He was the first member of staff of any ex-CAT University to be elected FRS. He had already had the earlier distinction, in 1980, of being the first Loughborough academic to be elected as a Fellow of the Royal Academy of Engineering. He is also a Fellow of the Institution of Mechanical Engineers and was a Member of Council of that Institution from 1965 to 1968. He is a Fellow of the Textile Institute and a Fellow of the Royal Society of Arts. He was the first British academic to receive the title European Engineer (Eur. Ing.) at a commemorative ceremony in Paris in 1987. In March 1990 he was awarded Honorary Membership of the Institution of Engineering Designers, the highest honour that Institution is able to bestow.

In 1976 Professor Wray was invited to give a Nominated Lecture to the Institution of Mechanical Engineers and was awarded the premier prize of the Textile Institute — the Warner Memorial Medal for 'outstanding published work'. In 1977 he was the nominated Springer Memorial Visiting Professor in Mechanical Engineering at the University of California, Berkeley. He also received a Certificate for Engineering Merit from the American Society of Mechanical Engineers, and was awarded the S.G. Brown Award and Medal by the Royal Society of London for his "contribution to the promotion and development of mechanical inventions". In 1980, he was invited to deliver the Brunel Lecture to the Annual Meeting of the British Association for the Advancement of Science. In December 1989, together with Dr M. Acar, he presented the 76th Thomas Hawksley Memorial Lecture on "The Supersonic Jet Texturing of Yarns" to the Institution of Mechanical Engineers, London.

Professor Wray has advised higher education institutions in many countries and has served on many national committees and working parties, including a Royal Society Working Party on Agricultural Engineering in 1981, the SERC Lickley Working Party on Engineering Design in 1983 and as Chairman of an Engineering Council/Design Council Working Party on 'Attaining Competences in Engineering Design'.

PART I : LECTURE BY PROFESSOR WRAY

1 The Evolution of the British University System with Particular Reference to Science, Engineering and Technology

Britain's famous Industrial Revolution owed very little to the universities. Its 18th Century creators were intensely practical, enterprising men such as Arkwright, Brindley, Cartwright, Crompton, Darby, Hargreaves, Kay, MacAdam, Newcomen, Trevithick and Watt. Their inventions all culminated in Britain becoming pre-eminent in the design, manufacture and transport of world-leading, high-quality capital goods. By the end of the 19th Century, however, competition had grown in other world markets and there were signs that Britain's lead was diminishing, with the development of mass production techniques, particularly in the United States. This lead had been greatly helped by a growing empire, with its captive markets and the provision of cheap raw materials, but it was largely due to the acquired knowledge of our innovative civil and mechanical engineers, which was related to their craft skills rather than to any appreciable understanding of science. They apparently used the laws of mathematics and dynamics somewhat intuitively without realising that these actually underlied their creative skills.

Following on these early inventions, almost a century elapsed before the scientific knowledge generated in the traditional universities and recorded in learned society journals began to influence the future shape of industrial change and innovation. Indeed, although many of the pioneers of British industry patronised education, few recognised that it had anything to do with the creation of the wealth that was paying for it. At the beginning of this century, it was being suggested by some concerned citizens that we should be learning lessons from several of our European competitors, particularly the higher technological education evident in the German *Technische Hochschulen* and the French *Grandes Ecoles*, because these were providing professional elite who both recognised and used the underlying scientific and engineering skills necessary for improving the development and production of all manufactured products.

Nevertheless, British society generally showed little recognition that higher education was essential for our international economic survival although, in Victorian days, the Mechanics Institutes had developed a system of technical education, mainly by part-time study. This was usually regarded as inferior to university education and was considered to be intended mainly for the working classes. It generated the snobbish ill-informed attitude that still prevails in the minds of many British citizens today; namely that technology is a type of study mainly suitable for the less able. The Victorian engineer was certainly not regarded as a professional in the same sense as were the lawyers, medics and clerics of that day; this is a status issue which still gives great concern to the major UK engineering professional institutes as they seek to recruit better entrants.

During the early years of the 19th Century, there were only two universities in England, i.e. Oxford and Cambridge, and these were concerned with the education of the sons of the landowners, who were mainly destined to join the learned professions of law, medicine and the church. Therefore, science had little place in their education, and those few College Fellows who professed and practised science were not held in high esteem by their colleagues. Nevertheless, there were some Britons who recognised that radical educational change was necessary at all levels if the British manufacturing lead was not to be completely lost to the growing competition of Europe and America.

English educational reforms led to the creation of the Mechanics Institutes and the Dissenting Academies, which usually arose from non-conformist movements to provide for more appropriate educational patterns than those being offered at the two existing English universities. The pioneers of these institutes and academies were men who displayed independence, since they were often merchants and manufacturers in the growing industrial areas.

By the end of the 19th Century, German exports had exceeded British exports. Germany was producing more educated engineers, many of whom were not only employed in engineering research and development but were also providing the essential business support services such as design and marketing. There was little doubt that the status of the engineer on the Continent was high, whilst in Britain it remained very low. This was a condition which prevailed at least until the Finniston Report (1) of only 10 years ago; this led to the establishment of the Engineering Council, which has made strenuous attempts to rectify this typically British anomaly.

Towards the end of the 19th Century, practical men raised money and appealed for public subscriptions for new university colleges in England, but these remained in perilous financial straits for many years until they eventually achieved government help. The university colleges became the large civic universities, mainly because they merged with local medical colleges. It is remarkable that, even though it was the largest city in the world, London had no university institution until 1828, when University College was founded. The University of Durham, which was established in 1836, was at first modelled very closely on Oxford and Cambridge, but in 1871 local industrialists helped to fund the Armstrong College of Science, which also provided for education in mining and engineering. Owens' College in Manchester, founded in 1851, became the Victoria University (including also the colleges at Liverpool and Leeds) in 1889. This federal University became the three separate civic universities of Manchester, Liverpool and Leeds in 1903. The Mechanics' Institute in Manchester (1824) was in fact older than the Owens' College (1851), but its successor, the Manchester College of Technology, became the Faculty of Technology (now UMIST) in the Victoria University of Manchester when Owens' College received its charter as a separate university in 1903.

Two well-known British academics, Sir Frederick Dainton (2) and Professor Geoffrey Sims (3), have each given detailed accounts of the difficult early years common to the new civic universities, since they all underwent a continued struggle for existence until 1920. State financial support for them was only on an ad-hoc basis and their principal output comprised graduates at the first degree level, most of whom became school teachers. Masters degrees by research were offered, usually part-time, and no PhD programmes existed. The state provided no scholarships. The only grants available for undergraduates were offered by the universities themselves from their scant resources. Fortunately, there were some far-sighted politicians who argued that the state should provide student grants or scholarships, as well as properly funding the universities to both teach and undertake research. They argued that scientific research was necessary for the nation's health, industry and defence.

The First World War exposed Britain's deficiencies in these fields and Britain's first Research Council, the Department of Scientific and Industrial Research (DSIR), was founded in 1916, followed soon afterwards by the Medical Research Council (MRC). Thus the Research Council system came into being, and in 1919 the University Grants Committee (UGC) was established, together with the Committee of Vice-Chancellors and Principals (CVCP); the PhD Degree (which probably originated in Germany) also started in Britain at this time. Therefore, the immediate post-First World War era marked the beginning of the dual-support system of UGC and Research Council funding.

The 20-years leading up to the outbreak of the Second World War in 1939 consolidated the growth of the civic universities. The pupils from maintained secondary schools gained an increasing number of university places, local authorities offered financial help and 200 state scholarships were established for the most able students. However, even by then, the total university student population in Britain was only 50,000, of which 40% were in the Oxford, Cambridge and London universities. Nevertheless, during this intervening period between the two World Wars, university research became accepted and the system was strengthened by the influx of refugee scientists from Germany and Austria. The Agricultural Research Council (ARC) was added to the two existing Research Councils in 1931. The number of industrial research associations grew during this 20-year period and government research, especially that related to defence, increased.

During the Second World War, the results of research undertaken by British scientists based on knowledge accumulated in the universities were evident in such developments as penicillin, radar, operational research and the first computer (known as the 'electronic brain'); biological research also yielded increased food production and higher nutritional standards. Of course, much of the scientific war-time effort of all the engaged nations was directed towards armaments, the most devastating being the atomic bomb that finally concluded the war. It was the effects of the war that brought to the British nation a public and political consciousness of the intense power of applied science, technology and engineering.

The post-Second World War period gave public recognition to the lack of qualified scientists and engineers, and government awareness of this finally reached its peak in the acceptance of the 1963 Robbins Report (4). This recommended that all who were qualified to benefit from Higher Education should receive it in the subject of their own choice. Then Prime Minister Harold Wilson, in implementing the Robbins Report, spoke about "the white heat of the technological revolution" when his government established the Ministry of Technology (now the Department of Trade and Industry), decreed that all the Colleges of Advanced Technology (of which Loughborough was one) should be redesignated as independent university institutions, and funded both the Polytechnics and the Open University. This movement, largely towards higher education in engineering and technology, was welcomed by those who believed that such studies should be more prestigious in the public eye and better catered for by the universities.

Meanwhile, the industrial situation in which engineers had to operate was itself changing from one which was product-led (i.e. the assumption that an excellent product will always sell), to one which was market-led (the need to create new markets for innovatory products). The engineer, therefore, had to accept the responsibility for producing well-designed products which had to be produced at a competitive price whilst being reliable and attractive to customers in terms of their performance.

During this post-war period of rapid university expansion, it was disappointing that UK industry generally did very little to encourage either education or training; this was increasingly left to the universities themselves. Much adverse criticism was made by industrialists about the unworldliness of the universities, and this was often well-founded. Similarly, some initially co-operative academics criticised industry for being unable to express what it really needed from universities, either in education or research, and this again was often true.

Industry called upon the universities to produce engineers who were cost-conscious with an ability to design and manage, but all too often engineering graduates were given little opportunity for career advancement within engineering companies. The demand for accountants and managers therefore grew, with attractive financial incentives, and it is estimated that currently 10% of all university graduates (20% of Oxford and Cambridge graduates) finish up in accountancy and similar financial occupations in commerce and 'the city'.

The number of graduates seeking to pursue management (MBA) courses is growing annually, and this is a welcome trend in improving British management standards, but the number of undergraduates wishing to study science and engineering is falling. In my opinion, it is a great fallacy for Britain to believe that it can continually increase the numbers of those involved in the control and management of its decreasing manufactured product base. Britain's serious Balance of Payments deficit in manufactured goods, currently standing at £16 billion annually, has been partially caused by a shortage of good engineers who can create products that can compete against other industrial countries (particularly Germany and Japan) where good engineering graduates have been more positively encouraged in salary, status and career advancement (5). Moreover, this decline in university science and engineering graduates has led to a tremendous problem in providing for good science teachers in British schools.

During the Robbins period of expansion in the late 1960s, a corresponding growth occurred in the Research Council system with the creation of both the National Environment Research Council (NERC) and the Social Science Research Council (SSRC), which later became the Economic and Social Research Council (ESRC); also the DSIR (which had been created in 1916) was renamed the Science Research Council (SRC), and this eventually became the Science and Engineering Research Council (SERC) in 1981. This expansion of national research funding further emphasised the importance of the dual support system between the Research Councils and the University Grants Committee, but this funding system has been questioned and changed by the present government, firstly by moving the responsibility for the UGC from the Treasury to the Department of Education and Science (DES), and secondly by the more recent decision that the UGC should be replaced by the Universities' Funding Council (UFC).

It was also decided that the Polytechnics and Colleges of Higher Education sector should receive a greater share of higher education provision directly from central government, rather than through local authorities, by resourcing them through a new body known as the Polytechnics and Colleges Funding Council (PCFC). According to the 1987 government White Paper, these two funding bodies have been created to "clarify responsibilities, improve financial accountability, and increase effectiveness". It was argued that the word 'grant' was somewhat outmoded whilst 'funding' was more appropriate to present-day needs.

The UFC has a larger non-academic membership and intends to allocate funds on a much more stringent basis. Therefore, all universities have recently had to undergo a competitive bidding process for university student numbers and courses. The indications to-date are that the new recommendations, coupled with other cuts in research and teaching expenditure, are causing some concern in higher education generally, although the need for greater efficiency is well-recognised and is indeed being readily acted upon within the university system.

Loughborough University of Technology has always been very strong in encouraging industrial support for its research (5) and indeed it was placed fifth in the league table of industrial funding of all British universities. Nevertheless, the Vice-Chancellor, Professor D.E.N. Davies, told the Annual Meeting of the University's Court on 31st January 1990 that those universities which derived research funding from industry and commerce, as opposed to the government-funded Research Councils, were being penalised by the policies of the new Universities Funding Council. The UFC research evaluation system has been criticised by many sources for favouring pure science and penalising those departments which undertake applied research for industry. Loughborough University of Technology had suffered from this effect and it was particularly notable that those Loughborough departments with a high proportion of industrial funding had not scored as highly as those which were primarily Research Council funded. The research funding of universities over the next five years will be based heavily upon the value of these research ratings.

The UFC has recently issued a report on its selection exercise, which has confirmed that this bias against applied funding is intentional and part of its policy. Extracts from this report state: "The focus of the Council's science research funding is towards basic and strategic work; for more applied research, universities are expected to seek funding from other sources", and "departments with high output of good quality pure science scored more highly than departments with a largely applied science bias; this is as it should be". Professor Davies stated that it is obviously absurd to expect universities to collaborate with industry on research if the UFC persists in labelling this as lower quality work, and he called upon the UFC to re-examine this area of its policy.

2 Engineering Qualifications in Britain

Although the universities were slow to encompass engineering studies (the first Chair of Engineering at Cambridge was founded in 1875), the ingenious men who inspired British engineering during the 18th Century were widely respected and the Institution of Civil Engineers was established in 1818. This laid the firm foundation of professional engineering in Britain and was followed by other Institutions, principally the Institution of Mechanical Engineers and the Institution of Electrical Engineers. Technical Colleges, founded on the basis of the Mechanics' Institutes (Section 1), sprang up throughout the country and these led to ONC and HNC qualifications and progressively through to professional chartered engineering qualifications based on corporate membership of these Institutions. The latter stage was usually attained by part-time study at the Technical College whilst concurrently following an engineering career in industry, followed by a period of professional responsibility after completing such part-time study.

Some 20 years ago, the UK professional engineering institutions jointly abolished such part-time routes to professional qualifications for prestige purposes and decided that every chartered engineer should be a graduate of a university or polytechnic before attaining the required training and professional responsibility standards required for chartered and registered status. The initial graduate stage was usually based on only three years of full-time study for an engineering degree, albeit it after obtaining A-level or equivalent entrance qualifications, which are generally higher than those necessary for entrance to the longer periods of undergraduate degree study at many other European universities.

After the Second World War, it became increasingly accepted that, whilst the three-year engineering course may have suited British industry during the early part of the 20th Century, the impact of rapidly changing technology was demanding substantial specialist educational skills. Nevertheless, successive governments avoided extending UK degree courses to those comparable with the continental practice, whereby the necessary speciality is additional to a sound basic educational engineering requirement. Therefore, for economic reasons, UK undergraduate education remains generally confined to three-year courses which have tended to become more specialised at the expense of the more general factors which are of fundamental importance in the real world of engineering industry. The only concession to this trend was the introduction of four-year extended degree courses (sometimes known as 'Dainton' courses) in the 1970s.

In recent years it has become increasingly necessary to use continuing education so that graduates can update their university education, by part-time study, in order to stay abreast of the constant stream of new and advanced technology. Integrated Graduate Development Schemes (IGDS) are an excellent example of such continuing education at postgraduate level, and the new modular MSc course in Engineering Design at Loughborough University of Technology, which is offered on either full-time or part-time basis (see Section 19), is another example of a flexible approach to continuing education in engineering in association with industry.

A government enquiry into the engineering profession led to the 1980 Finniston Report (1). This addressed the problems associated with a longer period of engineering education and training than had been considered adequate in the past.

It also advocated the possibility of transfer between the part-time and full-time routes of engineering education so that late developers should still be able to achieve the professional status that had been the case in pre-war years. It stipulated that 'Engineering Applications' should be compulsory with all engineering degree courses which were accredited through the professional institutions for the status and registration of 'Chartered Engineers'. The principal recommendation, however, was the establishment of an Engineering Authority, which would take over the responsibility for the registration of Chartered Engineers from the professional institutions. The Engineering Council was, therefore, set up in November 1981, but so far it has largely failed to obtain the resources from government for the encouragement of engineering education that both industry and academia had so largely expected after publication of the Finniston Report. Nevertheless, the continued flow of policy papers from the Engineering Council has been welcome and considerable changes have already taken place in universities and polytechnics regarding higher education in engineering, although these have occurred against a background of reduced financial resources from central government.

3 University Research and Industrial Exploitation (including Specially Promoted Programmes and Teaching Companies)

It has long been my view that engineering academics should endeavour to harness their researches to the needs of the engineering industries (5,6,7). However, immediately after the 1939-45 war, a considerable amount of money enabled academics to indulge in research which they felt to be of scholarly interest within their specialist areas with very little question about its value to the outside world. Grants were awarded by Research Councils on the basis of peer review, whereby each research proposal was scrutinised by prominent academics to ensure high quality and justifiable expenditure. The basic requirements were timeliness and promise but scholarly considerations seemed to prevail over the likelihood of commercial or industrial application. The arguments in favour of this system were that basic research in UK universities had a high reputation throughout the world. It was often stated that a greater proportion of British scientists achieved Nobel Prizes than was the case in any other country, although I personally wonder if that was in fact correct. Indeed, Britain produced a continuing stream of important scientific achievements in fields such as molecular biology, antibiotics, radio astronomy, nuclear magnetic resonance and semi-conductors, but it was often argued that the British capability for outstanding scientific research was not being matched by its application in UK industry, either by creating new products or by assisting industry to absorb new technology arising from these scientific and engineering breakthroughs. This formed the basis of the oft-repeated assertion that Britain is good at providing the basic research findings for other high-technology based countries (notably Japan) to apply to marketable products which we buy alongside other customers throughout the world.

During the last 15 years the SERC, together with the Department of Trade and Industry (DTI), initiated a gradual programme of change directed to the needs of industry.

Directorates in Polymer Engineering and Marine Technology were set up to enable collaboration between universities and industry in these fields, whilst simultaneously training research workers to work in the polymer and marine industries. The SERC also set up Specially Promoted Programmes (SPPs) for specified areas of importance, e.g. the Application of Computers in Mechanical Engineering (ACME) Programme and the Design of High-Speed Machinery, which has now become a Link Programme with DTI (see Sections 11 and 19). These and similar applications programmes generated so much enthusiasm that some academic researchers saw this as an attack on long-term basic research which, they claimed, was consequently being underfunded.

Another example of successful co-operation between SERC, DTI and individual industrial companies was the Teaching Company Scheme (TCS), which has provided nearly 400 interactive partnerships between individual industrial companies and universities or polytechnics. Each Teaching Company Programme is established to achieve a change in operation of the company. Bright young graduates are employed, usually for three years, to work on specific projects that are central to the company's corporate plan. The graduates have contracts from the academic institution and their work is supervised jointly by the academics and the company's executives. The participating company provides between 25% and 75% of the cost, the remainder coming from government funds.

The aims of the Teaching Company Scheme are:

1) to raise the level of industrial performance by the effective use of academic resources;
2) to improve industrial methods by the effective implementation of advanced technology and new ideas;
3) to develop able graduates for careers in industry; and
4) to involve academic staff in industry, enhancing research and the relevance of teaching.

4 Technology Transfer

Apart from agreed collaborative research projects (see Section 10) and special programmes such as the Teaching Company Scheme mentioned in Section 3, the problem of technology transfer remains important for applying the results of government-sponsored research projects to the needs of industry. Very often these results are published in scientific papers (which industrialists claim they have little time to read) or at conferences (which they say they have no time to attend). However, few academics realise that by publishing their novel findings in this way, they could be making prior disclosure of original ideas which would preclude patent protection for inventions relating directly to the results of the research (see Section 14).

The SERC Richards Report of 1975 highlighted the 'pre-development gap' which needed to be filled in order to convert a good research finding into a fully-developed and marketable product (8). We often talk glibly about our need for more R and D. In my opinion, this should be termed R,D and D, with the middle 'D' standing for Design (5). One does not develop research — one develops a design based on that research, and so the need for Research, Design and Development is becoming more important in the provision of higher value-added products with more 'knowledge content'.

The National Research and Development Corporation (NRDC) was founded by a government loan in 1948, mainly to transfer the results of university research (and the brainchilds of private inventors) to industrial application. NRDC sought to find suitable industrial partners to carry forward good university research ideas, for which it obtained a licence to pay for its own costs and to reimburse the university and the inventors for their efforts. Largely because it had some outstandingly successful products, mainly in the medical field, NRDC was profitable, although it was later absorbed as part of the British Technology Group (BTG).

In forming the BTG, the present government was anxious that BTG should not have the exclusive right to exploit inventions arising from SERC-sponsored university researches, but that this right should be open to competition from private-venture capital groups. Nevertheless, BTG continues to be the world's leading technology transfer organisation in licensing new scientific and engineering products to industry on a world-wide basis and in providing finance for the development of new technology. It takes the responsibility for patent protection of the inventions, as well as for negotiating licence agreements with industrial companies. Its net revenue is shared with the inventive source on an agreed basis.Since many inventions require further design and development before being licensed to industry, BTG sometimes provides finance for this as part of its technology transfer role. In cases where a particular technological innovation requires the setting up of a new company, BTG can perform a catalytic role in promoting the creation of start-up companies.

The innovative research that I and my colleagues pursued at Loughborough University of Technology, which led to the design and development of the Locstitch pile-fabric machine and process (9), was licensed to industry through NRDC. It is also my experience that BTG has been a very useful collaborator in several other textile engineering researches undertaken at Loughborough University of Technology (10). Furthermore, BTG has obtained patents to protect other Loughborough inventions, such as the Speckled Pattern Interferometer, which was designed by the Loughborough Optical Engineering Group as a non-invasive technique for the measurement of three-dimensional behaviour of structures and objects in their natural environment with unparalleled accuracy.

Applications are diverse — from the investigation of swaying skyscrapers and measurement of the stresses and strains in the submerged-leg length of oil-field platforms, through to the behaviour of arthritic joints. The Loughborough Speckled Pattern Interferometer is now being manufactured and marketed through two BTG licensees — Ealing Electro-Optic plc and the Newport Corporation of California. Many other BTG examples of successful inventions being transferred into industrial use have arisen nationally in fields such as meteorology, analytical instrumentation, advanced manufacturing technologies, process control and safety engineering.

5 Science Parks

Science Parks (11) originated in the United States, starting at Stanford in the 1950s, and led to the creation of Silicon Valley in California. Two famous students, Hewlett and Packard, gave great advertising prominence to this success, which by 1980 was said to have employed 26,000 people working with 80 companies, including the great Hewlett-Packard company, primarily in high-technology industry (12). In 1959, the Research Triangle Park in North Carolina came into existence by being situated in the triangle formed by three prestigious universities, and this now employs 22,000 people on a 5500-acre site. Similarly, Route 128 became a complex of industrial development, centred round the expertise in electronics at the Massachusetts Institute of Technology.

Apart from the availability of top scientists and technologists, they have often been provided with the advantage of reasonably cheap land by being situated in states suffering from unemployment and a depressed economy; for instance, the North Carolina Research Triangle (which I am familiar with at first hand) is in an area that suffers from the effects of the declining tobacco industry, and therefore state taxes have been lowered to attract new industries. The resident companies have also benefited from the availability of venture capital on favourable terms. Although these are some of the notable successes, it is true that several Science Parks in the United States, including some associated with major universities, have failed.

The Science Park concept found its way to Europe some 20 years later and Britain became one of the main areas for such ventures. The best known is probably that at Cambridge, which was started in 1969 when land owned by Trinity College was made available on very favourable terms. Today there are some 30 Science Parks in the UK, and these fall into three distinct categories (12).

Firstly, there are the Science Parks that are almost entirely ***university-led and funded,*** as in the Cambridge case, where the University has established the Science Park using its own or borrowed finance and has continued to be responsible for all the development and management functions. Later schemes, such as those at Herriot-Watt and Surrey Universities, continued in that style. The Surrey Research Park is owned by the University on land purchased via a charitable trust from funds which were raised in the 1960s by public subscriptions. Therefore, like Cambridge, its land charges were held at a relatively low cost with no interest charges. However, the Brunel University Science Park suffered financially because the UK Treasury was said to have 'clawed back' 50% from the sale of the first ground lease, as this involved government money.

The second classification of Science Park funding is by ***joint-venture companies.*** The joint-venture company provides a vehicle through which the control and management of future development may be co-ordinated. For instance, Aston Science Park was established in 1983 by Birmingham Technology Limited, a private company whose partners are Aston University, Birmingham City Council and Lloyds Bank. Warwick Science Park is similarly run by Warwick University in partnership with the Coventry City Council, the West Midlands Enterprise Board and Warwickshire County Council. Similar arrangements are seen at the Manchester Science Park and at several other university venues.

The third method of funding is the ***co-operative venture strategy***, which does not involve any separate legal company and is therefore more flexible. Usually, a local authority or development agency takes the leading role and provides the major financial input. The Technology Centre at Loughborough is a typical example of this, although it is planned that the University will have a larger Science Park when the national British Gas Company brings its research and development activities onto the Loughborough University Campus; this will form the nucleus of a much greater enterprise over the next few years. Other smaller co-operative ventures are associated with the universities at Bradford, Leeds, Hull, St Andrews, Aberystwyth, Durham, Bangor, Kent, Stirling and Swansea.

Nevertheless, not all Science Parks need to be associated with universities and polytechnics, and the Bolton Technology Exchange was opened in 1986 as a joint venture between Bolton College of Higher Education, Bolton Metropolitan Borough Council and English Estates. English Estates are a very large national developer and manager of industrial and commercial property and have been prominent in the development of many Science Parks throughout the country, most notably the Listerhills Science Park at Bradford University.

Generally speaking, the Science Park is a property-based initiative which:

- has formal operational links with a university or other higher educational institution;
- is designed to encourage the formation and growth of knowledge-based businesses normally resident on-site; and
- has a management function which is actively engaged in the transfer of technology and business skills to the organisations on-site.

Therefore, Science Parks have two main objectives in that, firstly, they are to encourage technology transfer by reducing the time lag between innovation and the production of new products; and secondly, they are intended to provide means of encouraging the establishment and growth of high technology industry in order to generate wealth and employment in the neighbourhood. There is no doubt that, in several instances, these objectives have been achieved, but there have been problems.

A dialogue has to be established between the companies and the universities, and in many cases there needs to be considerable interaction with local authorities and financial institutions; therefore, a climate of mutual confidence and respect has to be created. Unfortunately, in many cases there has been a low level of technological interchange, and this has frequently been blamed on the universities. However, industry itself is subject to criticism on this front, in that often the UK industrial companies do not respect academic values and know little about how to use the talent prevalent in the academic environment. Again, if local authorities tend to resent the higher educational institutions in their locality, this can generate problems. The successful Science Parks thrive on a high standard of buildings situated in a very desirable location. The continued commitment of the university is essential so that academics are constantly aware of the Park's existence and are willing to co-operate in innovative ventures on it.

Indeed, one of the prime objectives of most Science Parks is that the university itself should form new companies based on innovations springing from its research, as was the case with Messrs Hewlett and Packard at Stanford. However, even when favourable conditions are provided, such as the provision of adequate buildings at advantageous financial rates, they are seldom filled with new enterprises, and even when they are, they are sometimes hardly associated with high technology. Sometimes the important factor is the general ambience of the location rather than the availability of the adjacent university staff's expertise in science and technology.

Perhaps it is too early to judge the success of British and, indeed, European Science Parks, because they have as yet not reproduced the spectacular successes of the early United States developments. It is probably a fact of life that, in the present British economic climate, venture capitalists are inclined to be less venturesome than their American counterparts in that they prefer to invest in existing business expansions and management buy-outs rather than in the much riskier world of starting up new businesses.

Apart from Specially Promoted Programmes, Teaching Company Schemes and Science Parks, many other types of university/industry collaboration exist in Britain. Sections 6 to 16 of this paper have as their principal source of reference a very comprehensive recent report by the Department of Trade and Industry and the Council for Industry and Higher Education (13).

6 Directly Sponsored Industrial Research and Consultancy

In directly sponsored industrial research, the company is able to specify its own objectives and criteria for success in return for a fee from the university. This is usually for very specific projects and consultancy. Sometimes it can be based on the development of a prototype, but it is usually associated with product and process testing. The benefits to the company are that the university provides the staff and equipment that the smaller companies cannot afford to maintain, the company can define the aims and outputs fairly tightly, and there is the possibility of a good cross-fertilisation of ideas.

7 Industrial Fellowships or Studentships

By providing fellowships or studentships, companies (sometimes with government aid) can fund research workers on specific research projects of direct interest to them. The company may offer in-house facilities, such as workshop and manufacturing expertise, whilst the student will have access to the university's libraries, laboratories and computer facilities. As will be discussed in Section 14, the property rights of the university workers need to be established right at the outset, together with any confidentiality placed upon the outcome of the research, bearing in mind that the university would naturally wish to publish the results in due course.

This type of industrial support is suitable for a company wishing to contribute to research by the use of its facilities and expertise, but not by major funding. It is useful in instances where the research would benefit from the guidance and advice of a senior academic who could act as supervisor to the student. The benefits to be obtained are that the company gains access to expertise at a reasonable price and contributes to the training of young research workers who may eventually be of use to the company in full-time employment. It is a cost-effective way for smaller companies to stay abreast of technological developments and government agencies may provide part-funding, for instance through the Teaching Company Scheme (Section 3) or through SERC CASE Studentships (Section 8).

8 CASE Studentships

The SERC's scheme for Co-operative Awards in Science and Engineering (CASE) involves a postgraduate student undertaking a project which is jointly devised and supervised by the academic and industrial partners. The student usually presents his or her thesis after 12 months work for an MSc or, if the project extends for that long, after three years for a PhD. Universities are given a quota of CASE awards and the commencement of projects is between August and November of each year. The objective is to undertake research on behalf of industry, mainly in the university, by using its equipment to work on a project of commercial significance to the particular company.

The student must spend at least three months of a three-year project in industry. SERC supports the research with a studentship and pays the university fees for higher degrees. The company provides the necessary materials, travel and recurrent costs and can provide a bursary to increase the maintenance element of the studentship by a value of about £100 per annum. SERC also expects the company to pay the student's out-of-pocket expenses whilst in industry and to make a modest contribution in cash and kind to the university to support the running costs of the project.

9 Research Clubs

A research club is an association of companies with one or more universities whose purpose is to collaborate in research or to encourage technology transfer. The membership of the club usually involves a subscription and the project is specific to a technical area or sector of industry of interest to the sponsoring companies. The companies may wish to support or keep close to a developing area of research, and members should be able to partake in the dissemination of results and the stimulation of new projects within the general subject area. This type of research is suitable for projects where a company is prepared to negotiate aims and benefits with others who may actually be competitors. A greater range of expertise can, therefore, be applied to technical problems, and the cost to individual company members can be shared.

Typical research clubs are those in Protein Engineering at Oxford Polytechnic, Bio-Medical Signal Processing Clubs at Imperial College, London, and the newly established Institute of Optical Engineering at Loughborough University of Technology.

10 Collaborative Research Projects

In a collaborative research project a company or group of companies can assist in resourcing and defining the project where commercial exploitation of the research work is not directly forseeable. Examples are research areas where the theory or principles are not well developed. The government (through SERC and/or DTI) will award funds to the university workers on the condition that industry also jointly sponsors the research. It is applicable where the company does not need to negotiate its own objectives or its rights to the results, but is not suitable for near-market research, either because of the numbers of companies involved, or because the university would wish to publish the results widely.

A typical example of a large collaborative research project is the Alvey Programme in Information Technology. The benefits are that an individual company can encourage the development of an area of basic research in which it has an interest, without itself committing substantial resources, while ensuring that company researchers stay in touch with developments in the particular research area.

11 LINK Programmes

LINK Programmes are intended to accelerate the commercial exploitation of British government funded research in areas of science and engineering with particular commercial promise. They are supported jointly by the DTI and the SERC. Industry and higher education institutions are encouraged to speed exploitation and develop profitable marketing approaches by collaboration. A variety of LINK programmes exist, for example:

- industrial measurement systems
- molecular electronics
- advanced semiconductor materials
- food-processing sciences
- the design of high-speed machinery.

The LINK support is usually limited to 50% for projects related to strategic research.

12 Regional Technology Centres

The Regional Technology Centres (RTCs) were established in Britain by the DTI, the DES and the Training Agency, whereby Higher Educational Institutions and local firms collaborate to ensure that companies are fully informed about technological developments, particularly in local regions. This co-ordinates and encourages the flow of technical knowledge between the universities and local businesses. It maintains a database of technology transfer opportunities and provides training in the introduction and management of technology. The RTC also develops access to national information or new technology which may be of particular benefit to local industry.

13 University Directors of Industrial Liaison (UDIL)

This is a network of industrial liaison officers working in 89 UK universities and its role is to promote understanding and collaboration between industry and the universities. Its activities are meetings and conferences for members and publications to help industry by providing, amongst other things, a directory of industrial liaison officers and the research interests of their particular universities. The individual members are able to advise companies on the way their universities can help with research, training, consultancy and testing services.

14 Intellectual Property Rights

For any type of industrial and university research collaboration, the important matter of intellectual property rights needs to be anticipated right at the outset of the research project. Questions of ownership of rights are easily overlooked before the property to be protected exists, and a contract covering their possibility will forestall wrangling when such rights materialise. The ability to protect and exploit any rights arising out of research will depend upon the circumstances in which the research takes place. This usually falls into one of the following categories:

1) Where research is carried out by academic staff as part of their customary activities, exploitation is then a matter between the university as an employer and the academic staff as employees;
2) Where research is carried out with the support of Research Council grants, exploitation is then generally the responsibility of the university (see Section 4);
3) Where the research is carried out with the support of money from bodies other than Research Councils, for example private companies, it is up to the partners to ensure that provision for exploitation is made in the relevant contract drawn up at the outset of the research;
4) Where research is carried out by students or fellows, and therefore not by an employee of the university, the student or fellow should be a party to a contract drawn up by the university and by the sponsoring body employing the student.

Academic inventors should be alert to the commercial possibilities of intellectual property (see Section 4). Here organisations like the British Technology Group (BTG) and Loughborough Consultants Limited (LCL) are very useful in considering the following factors:

1) The initial proposal for research may contain an idea that needs patent protection. Proposals should therefore be discussed at the formative stage with any staff in the university responsible for registration and exploitation of inventions (usually this is done with the agreement of the Head of the Department in which the research is conducted);
2) All current research activities should be reviewed regularly and systematically, by an evaluator with experience of the appropriate markets, to identify as early as possible any exploitable potential, which could include computer software specifically developed for the project;
3) It is important to keep a note of the time and date at which a member of staff reports an invention and claims to be the inventor; and
4) It is essential not to publish research findings prematurely. There is a need to make sure that the property is protected before any publication, as this often results in a patent being unobtainable due to the prior disclosure in a publication.

The potential for exploitation of intellectual property needs to be evaluated for its scientific validity, commercial potential, originality, protectability and further development. The services of a patent agent may be useful here, but if discussions take place with other third parties care should be taken to ensure that such discussions are protected by confidentiality agreements.

Several methods exist for exploiting the property rights:

1) The university may assign the rights to a third party, as part of a revenue-sharing agreement, as is usually the case with the BTG procedure (see Section 4). Provision should be made for the return of the rights to the university within a specific time period should the assignee choose not to proceed with the exploitation;

2) Licensing a third party to develop, manufacture and distribute the product after a patent has been granted is a commonly employed method. Separate licences can be granted by the university for different companies, perhaps in different countries, to proceed with the exploitation. It may also be possible to grant the licensee the right to sub-licence; and
3) Many universities have established companies in order to exploit a right, usually in the form of manufacturing or selling a product. In 1969, Loughborough University of Technology was the first university in the UK to establish a commercial company, Loughborough Consultants Limited, on a British university campus. Among its activities, LCL is experienced in this type of commercial exploitation. The use of a campus-based company may be appropriate when the considerable start-up costs are expected to be recovered from successful marketing of the product.

The exploitation of the invention needs to be followed up with careful records and accounts to ensure that timely statements of sales and royalties or licence fees due are received and distributed promptly. It is often the case that the industrial company exploiting the research needs constant reminders from the university to pay the royalty due to the university, since many companies like to keep their hands on any money received for as long as possible.

Very often the researchers have a better idea of the companies to be identified as possible partners than either the university or even the BTG. Therefore, the university staff should be willing to assist in identifying companies capable of producing the product efficiently and selling and distributing it in the chosen markets. The university should also be willing to help the company in the further development, since the research workers will often have the intellectual know-how and skills to ensure that the embryo product is successful and that an adequate after-sales service can be provided.

Typical examples of this, drawn from the author's own experience, were the Locstitch pile-fabric machine and process (9) and the ART (Automatic Rib Transfer) machine for fully fashioned garment manufacture (14). The first of these innovations involved the University staff workers themselves specifying a market requirement arising from their own observations of inadequacies in conventional methods of pile-fabric manufacture. Industry showed little interest in the new machine and the novel process, until a working prototype rig had been developed via a SERC grant. In the second case, an industrial company (Corah plc) specified the market need, and sponsored the design and development of the ART machine under the leadership of Professor R Vitols, an inspired designer who saw the commercial potential of earlier SERC-sponsored research at the University (15). In both instances, it proved necessary for the academic staff teams to be fully involved in the total innovation through the stages of invention, research, design and development, right up to the industrial prototype stages and even beyond this into the after-sales service stages.

Sometimes a university will find it advantageous to have a further contract regarding the continued co-operation of the university staff beyond the terms of the initial agreement. Such follow-up work can be very demanding of university staff time and facilities, and therefore the university and its employees would wish to be recompensed for such further work. The university should have an officer responsible for overseeing the terms of all licence agreements so that good records are kept of income due and received, and prompt distribution to those having an interest in the innovation.

The following points, summarised from publication (13), are the costing and pricing implications in dealing with property rights and the pricing of research contracts:

- the university should consider the true value of the resulting intellectual property;
- it should only dispose of its rights to exploit intellectual property in consideration of the true value;
- background intellectual property which is to be used in the research project should be added in the costing of the contract, as should the use of know-how; and
- agreements to reward academic staff for their contributions to a successful exploitation should be negotiated according to the individual contributions of the inventors and researchers.

15 Costing and Pricing of Industrially-Sponsored Research Projects

From Sections 6, 14 and 16, it will be realised that a university needs to ensure that it charges a proper price to the commercial customer, in that when it provides such a service there should be a true relationship between the cost of the service and the price charged for it. Therefore, the true cost must first be identified. The company involved in the contract will also be reassured if it is evident that a reasoned approach to the charging of services has been taken. Academic staff should be encouraged to take responsibility for costing their own projects, and there is a need for a consistent approach to costing across the whole university to ensure that all costs are identified. For instance, Loughborough University of Technology has prepared an internal booklet entirely devoted to the costing of research projects, and this contains much valuable information.

Inevitably, there will be a proportion of indirect costs which cannot properly be charged to any specific project or activity; however, whenever it is administratively convenient to identify and apportion the costs of services as direct costs, this should be done in order to keep the proportion of indirect costs (and the potential for argument about the definition and relevance of overhead charges) to a minimum. The Committee of Vice-Chancellors and Principals (CVCP) has published a methodology for costing projects (16) and recommends the practice of levying indirect costs on the payroll costs of all the staff engaged directly on the project. This approach assumes the following definitions of types of cost:

1 **Capital Expenditure** covering investment in buildings, plant and other major items of equipment.

2 **Recurrent Expenditure** covering all operating costs of the university, which can be divided into:

   a) direct payroll costs for staff engaged specifically for the project and time spent on the project by members of the permanent staff;

   b) other direct costs such as those incurred directly on the project, including consumables, new equipment and services, and the usage of existing equipment and services which can be properly attributed to the project; and

   c) indirect costs (overheads) incurred on goods and services in support of all the institution's activities which cannot be readily attributed to any particular project.

To summarise, it is good practice to have an institutional policy for costing and pricing. The university should develop clear rules on who negotiates contracts and prices and how much discretion should be permitted. It should keep accounting systems as simple as possible and suitably train all staff involved in negotiating, costing and pricing contracts. It should also provide regular relevant reports to project managers to allow the careful monitoring of income and expenditure.

16 The Management of Collaborative Research

Industrial-academic collaboration in universities can bring substantial benefits to both partners, but the venture needs to be carefully managed (13) because research is a special kind of activity, and academic and industrial culture may have contrasting views on the matter. For instance, industry (particularly small companies) does not always appreciate that research is unpredictable and that results cannot be delivered to order. Moreover, time-scales are long and 'breakthroughs' rarely happen quickly. Research work involves risk and research managers have to be prepared to deal with failure. Even when the results are promising, the time that will elapse before commercial exploitation might be measured in years rather than months. Whilst research is a day-to-day activity at the university, within a company it may represent a new departure and a new field of investment. The company should be aware of the fairly long time-scales involved and may wish to make a considered assessment of the likely implications before becoming involved in sponsored research.

Contract research demands skilled research workers, trained support staff and, often, specialised equipment and materials. The results will usually have to be tested, piloted, developed, manufactured and marketed before they will earn any revenue for the company. Therefore, all those involved need to understand the co-operative objectives of the company and that arrangements for exploitation of the results are clear (see Section 14). The project needs to be properly costed, as stated in Section 15, with no hidden assumptions about extra resources being found later once everyone is committed to the project. Therefore, the budget planning needs to extend sufficiently far enough ahead to provide a stable basis for managing projects. In other words, the industry needs to be committed to seeing it through, even if the first results are not very promising.

Therefore, companies should ask themselves at the beginning of the negotiations the following key questions, which are abstracted from publication (13):

- What do we want from this collaboration?
- How will we measure success?
- Is the university conversant with the context of the requirement?
- Do we understand the motivation of the university staff?
- Can we contribute to their objectives without adding significantly to the costs?
- Are we restricting their freedom to deliver?
- How much is the research worth to us and how much would it cost to do it in-house?
- Do we get any incidental benefits from the association with the university?

The university should ask itself:

- Has the problem been correctly defined by the company?
- What are the company's deadlines and why are they important?
- Can we deliver to their requirements, on time and within the agreed budget?
- How much would it cost us and have we included all our indirect costs?
- What benefits will the university get from the project?

Careful consideration of these questions, and truthful answers to them, help the partners to understand their different points of view. The chances of failure will be reduced if each appreciates the other party's priorities and constraints right at the beginning of the research. A successfully managed project creates a climate of confidence for further collaboration. Reaching agreement in a written contract and then failing to work successfully together makes both parties very reluctant to repeat the experience.

Before concluding this section, I ought to state my own personal view that a large disincentive which handicaps university staff, and discourages them from embarking on industrially-sponsored research, is that it does not conveniently lead to traditional learned society publication — which is still a primary requirement for academic promotion.

Often, because of trade secrecy and the possibility of 'disclosure' to competitors in the international market, much sponsored research has a confidentiality clause which precludes normal publication. Even with SERC/industry collaborative projects, it is sometimes difficult to publish because of the need for UK exploitation of inventive ideas which could provide the 'competitive edge'. Publication is also discouraged by BTG and other venture capital organisations because of possible 'prior disclosure' problems of unpatented information (see Section 4); to patent early is often unwise because of the need for expensive international protection after one year when the provisional patents expire.

It is therefore necessary to keep such inventive research findings extremely confidential until they approach the exploitation stage, but by then the lead-time on publications could cause them to be of reduced relevance because of similar developments elsewhere. This discourages publication, and staff undertaking such work often find it difficult to climb the academic ladder. Loughborough University of Technology has attempted to overcome this problem by taking into account research income for promotion purposes. To publish does not merely mean to print on paper — it means to make generally known; where it is known by the University that a staff member has contributed to advances in industrial products, processes and systems but cannot publish for confidentiality reasons, this should be recognised in the consideration of university staff promotions.

17 Research Sponsored by the European Commission (EC)

An excellent guide to European collaboration in science and technology was published in 1987 by the Science and Engineering Policies Studies Unit (SEPSU) of the Royal Society and the Fellowship of Engineering (17). The EC devotes about 2.5% of its budget to R and D, and the various research projects take a number of forms.

In the shared cost programmes, an official invitation to submit applications (call for proposals) is published in the official journal of the European Communities. This announcement is often preceded by a call for an expression of interest. There is usually a two- to three-month gap between the call for proposals and the deadline for submission of the completed proposal form, but a partnership of organisations in at least two member states is an essential condition for most projects. The selection process, which includes review by independent technical experts, is conducted entirely on the basis of the written proposal.

The normal maximum EC contribution for industry and other organisations, apart from universities, is 50% of the full economic costs, including overheads, within an overall ceiling. Universities and similar higher education establishments may receive up to 100% of marginal costs, including many overheads subject to an overall ceiling, but excluding the time of permanent academic staff. When a university has an industrial partner, the contribution from the EC to marginal costs is normally limited to 50%. In such cases, it will often be convenient if the university is a subcontractor.

A brief technical report is required every six months, and a final report (or an agreed edited version that omits commercially sensitive information) must be made available for publication. Some typical EC programmes are detailed below:

1 ESPRIT (European Strategic Programme for Research and Development in Information Technology)

The aim of ESPRIT is to provide the European Commission's information technology industry with basic technologies through collaborative pre-competitive research and developments. Projects must involve industrial partners in at least two EC states, and most projects include a university and an average of four companies. The fields covered are:

- micro-electronics and peripheral technology;
- information processing systems; and
- applications technologies.

The original ESPRIT programme was launched in 1983 and proposals for a second round of projects (ESPRIT II) closed in June 1988.

2 BRITE (Basic Research in Industrial Technologies for Europe)

3 EURAM (European Research on Advanced Materials)

The latter two programmes aim to make industries more competitive through research in industrial technologies and advanced materials. The funding is for collaborative research from 1989 to 1992 on:

- advanced materials technologies;
- design methodology and assurance of products and processes;
- applications of manufacturing systems; and
- technologies for manufacturing processes.

18 EUREKA Conference

EUREKA stands for the European High Technology Programme sponsored by a conference of ministers of European countries and the EC. Britain is represented by the Department of Trade and Industry (DTI). The aim is to promote trans-frontier collaboration in Europe on industry-led high technology research and development projects. The funding is available for projects carried out by companies in two European countries, possibly in collaboration with a university. The level of support will depend upon the national scheme. The project should be aimed at a widely marketable product, process or service in order to secure a significant high-technology advance.

19 Industry/University Collaboration in Engineering Design Projects at Loughborough University of Technology

Apart from the Locstitch and ART machines referred to in Section 14, I and my colleagues in the Mechanical Engineering Department at Loughborough University of Technology have had many other engineering design-oriented collaborative research projects with industry. These include:

- noise reduction in synthetic fibre machinery (18);

- noise reduction in shoe machinery (19);
- weft-knitting machines (20);
- synthesised mechanical linkages (21, 22);
- automatic clothing assembly (23);
- supersonic jet texturing of yarns (24);
- unconventional fabric and yarn machines (25); and
- a computer-controlled machine for artificial ligaments (26).

These design-based researches were largely supported by SERC, but all involved either direct industrial participation or indirect company support in the form of hardware and/or technical advice; this was usually significant to the investigation's successful outcomes. Not only does such collaboration provide innovatory machines for the UK manufacturing industry, but it is also a highly contributory factor in encouraging creativity in the education of undergraduate and postgraduate engineers.

Industrially-based design projects provide an opportunity for students to investigate real-life problems and thus develop their design abilities knowing that the solutions are likely to meet a timely industrial need (15). Student motivation increases when they become aware that they are conducting design exercises which have more than an academic interest (27). Furthermore, academic/industrial collaboration enables lectures and case studies to be presented in the light of first-hand ongoing experience by the lecturers concerned; they are able to highlight the product and process economics and their social implications by emphasising that their recent design experience is based on the demands of a real, competitive environment.

In endorsing the Report (28) of the SERC 1983 Lickley Working Party, on which I served as a member, the Engineering Board of the SERC has at last recognised the importance of research in engineering design by encouraging higher educational institutions to submit collaborative grant applications with industry and with the emphasis on design rather than on research alone. In 1984, all the engineering committees of the SERC altered their terms of reference to include design in their remits. The SERC Specially Promoted Programme in the 'Design of High-Speed Machinery', which has since become a DTI LINK Collaborative Research Programme (see Sections 3 and 11), was launched in 1985 with seven examples taken from the many high-speed and automatic machinery researches undertaken by colleagues and myself in the Mechanical Engineering Department at Loughborough (10). Current examples of such SERC/DTI/industry-sponsored research into the design of high-speed machines in that Department include:

- friction spinning (Platt Saco Lowell);
- mingling nozzles (Rieter Scragg);
- ultrasonic forming (Metal Box);
- can manufacture (Metal Box);
- fast-operating clutches; and
- piezo-electric high-speed actuators regulating discrete motion controlled drives.

If British universities are to progress in effective design-oriented research, this needs to be directed towards using largely existing knowledge in creating new devices, processes, systems, circuits and so on, and will usually require an interdisciplinary teamwork effort. It will certainly involve all types of specialists, provided that they are prepared to recognise that the ultimate objectives in the application of their specialist disciplines is superb design. As Director of the new Engineering Design Institute at Loughborough, I hope to extend this type of research activity across all departments of the university and across a wide range of industrial companies. The companies will assist in the joint assessment of design projects, particularly in respect of the recognition, identification and specification of industrial needs in light of the current economic climate and the rapidly changing levels of today's technology.

Many Loughborough departments have extensive records of design-related research. Most of this work is funded jointly by industry and the SERC, with an increasing number attracting support from European Community schemes such as BRITE and ESPRIT. The total 1988/89 external income across the University associated with the design activity exceeded £5 million. The Engineering Design Institute hopes to further encourage collaborative inter-departmental design research whereby the experimental programmes would be undertaken in the major department, and inter-departmental research teams would be seconded to the EDI to ensure an efficient interaction between disparate groups of specialist researchers. The work envisaged for this EDI co-ordinating activity covers a wide range of projects relating to the design of products and processes for the wealth-making sector, and the development of new design methods and advanced design tools. The Institute, in close collaboration with the rest of the University's research community, intends to undertake campus-wide design research projects which require combinations of advanced knowledge and facilities in areas such as robotics, mekatronics, manufacturing systems, electronics, process technology, software engineering, structures, transportation systems, human factors, management and industrial design.

In addition to being a catalyst for inter-departmental research, EDI staff have research strengths in a number of new fields with a high potential for industrial application. Included in these fields is Design by Features, which aims to provide design engineers with a user-orientated method of defining engineering components and features on computer-based 3D modelling packages. The Design by Features approach also provides a tool for storing information in a required format for fully-integrated CIM systems.

A further design research activity being pursued by EDI staff is the linking of 2D and 3D computer modellers to knowledge-based systems through transparent user interfaces, thereby providing for the design of technologically advanced products, processes and systems.

There is a great need for fundamental research into the design process itself by an Expert Systems approach involving Artificial Intelligence. In the same way that robotics has tended to replace tedious human operations in manufacturing processes, so it is true that some of the designer's decisions can also be tedious and somewhat repetitive and could perhaps be accomplished by computers. To undertake this considerable task will call for the interdisciplinary approach mentioned above. A satisfactory outcome could yield great benefits and would certainly justify the long-awaited realisation of the need for research in engineering design.

The Engineering Design Institute has recently been encouraged in its intended interdisciplinary approach to design by an award of £125,000 from the Wolfson Foundation for an extension to its premises to be known as the Wolfson Research Laboratory for Engineering Design. This will not only provide welcome additional space for postgraduate researchers, but will also provide a computer applications laboratory and extended modelling facilities for design-related research projects.

The prestigious new Chair, which I have the honour to hold, namely The Fellowship of Engineering Chair in the Principles of Engineering Design (which also has financial sponsorship by the Institution of Civil Engineers and the Institution of Mechanical Engineers), has been newly created with the objective of collaborating with engineering departments in developing a common interdisciplinary approach to the teaching of the principles of engineering design to all Loughborough engineering undergraduates. Therefore, one of the prime objectives of the Engineering Design Institute is to work with staff of other departments in the co-ordination and teaching of design to undergraduates. The Fellowship of Engineering has since instituted industrial visiting Professorships in the Principles of Engineering Design at the Universities of Aberdeen, Durham, Hull and Oxford.

As one would expect at a University of Technology, Loughborough has always made a strong feature of the teaching of design in its engineering undergraduate courses. In the machinery design researches mentioned above, the contributions made by students have proved invaluable. From the educational viewpoint, their involvement has enabled them to become more effective in the recognition of market needs, in innovative activities, and in the analysis and optimisation of the real-life solutions to current engineering problems.

Another example of this is the Teaching Contract, of which I was the founder Director nearly 10 years ago (29). Initially this had pump-priming support from DTI, but is now entirely funded by the collaborating industrial companies.

Second-year Mechanical Engineering students perform group design studies put forward by industry, which are real industrial problems involving constraints of time and money. A more recent addition has been project designs that are part of a Total Product Design topic in the third academic year, again supported by collaborating companies. Both of these design exercises are supervised by company engineers in collaboration with the departmental academic staff, and they are also involved in assessment and marking which contributes to the degree award. Similar practical design exercises are to be found in the formation of all engineers at Loughborough.

Regarding postgraduate education leading to Masters degrees in engineering design, Loughborough was the pioneer in that the Engineering Design Centre was established for this specific purpose in 1966, the same year in which the University obtained its charter. Unfortunately, British industry generally gave little support to providing full-time British students for the MTech course, although many overseas students were attracted to the Loughborough Engineering Design Centre. After Loughborough had been doing it for nearly 20 years, the 1983 report of the SERC Lickley Working Party on Engineering Design (16), on which I served as a member, strongly recommended that there should be short courses or linked modular courses in specific design topics and that the SERC should seek ways of supporting such short courses.

The *Academic Plan to 1990* published by Loughborough University of Technology in February 1987 stated that: "The University is committed to establishing an Engineering Design Institute (EDI) which should be an independent department within the School of Engineering working closely with the other engineering departments and with the Department of Design and Technology". The Institute, which has subsumed the existing Engineering Design Centre, now has six members of academic staff plus supporting technical and secretarial staff and occupies a specially refurbished and re-equipped building within the main engineering complex.

All of the Institute's enquiries to industry have shown that postgraduate design courses of twelve months duration are largely unacceptable for staff already employed in industry, and therefore the new MSc course, which commenced in October 1990, is on a modular basis in order to be suitable for either full-time or part-time study. There is also the additional attraction of offering the individual lecture modules as 'stand alone' short courses for the benefit of those who wish to update their knowledge without undertaking either of these postgraduate courses.

The modular MSc course in Engineering Design at Loughborough University of Technology is based on the premise that design is a total activity involving all the engineering and related management disciplines that are necessary to provide an artefact (i.e. product, process or system) to meet a market need; it commences with the identification of the need and is not complete until the resulting artefact is in use and providing an acceptable level of performance. The course content has been carefully structured to show the critical importance of effective engineering design to national wealth creation. As well as preparing postgraduate designers to be effective managers of the engineering design process, it will provide them with a working knowledge of the latest technological aids. It will also stress the importance of industrial design and human factors in the provision of marketable products. A major design project, undertaken with industrial co-operation, is central to the course.

20 Conclusion

I hope that this paper has given some indication of the opportunities for State-Industry-University linkages in research and teaching, particularly as practised in Britain. Of course, examples could be found in many British universities, but I have, naturally, drawn from my own experience at the Loughborough University of Technology.

References

1. FINNISTON, Sir Montague (Chairman), *Engineering our Future,* Report of the Committee of Inquiry into the Engineering Profession, Cmnd 7794, HMSO, London, 1980.

2. DAINTON, Sir Frederick, *Universities and Industry: Creative Tension or Cosy Cohesion*, Stamp Memorial Lecture, University of London, 31 October 1983.

3. SIMS, G., The Universities, Chapter 2, and Engineering, Chapter 5, IN *Universities, Education and the National Economy* (editor, Michael D. Stevens), Routledge, London and New York, 1989.

4. ROBBINS, Lord (Chairman), *Higher Education,* Cmnd 2154, HMSO, London, 1963.

5. WRAY, G.R., *Design or Decline - A National Emergency,* Inaugural Lecture, Loughborough University of Technology, 16 May 1990.

6. WRAY, G.R., *Technology - the Resource of Brainpower,* Invited Lecture presented at the Hilton Hotel, London, to a Senior Management Conference of the Institute of Practitioners in Work Study, Organisation and Methods on "Resources, Technology and People",28 November 1974; published in *Work Study and Management Services*, 1975, Vol. 19, No. 1, pp 14-27.

7. WRAY, G.R., *How can University Engineering Research be directed to the needs of Manufacturing Industry?*, the Brunel Lecture at the British Association for the Advancement of Science Annual Meeting 1980; published in *Engineering Challenges in the 1980s,* Vol. 1, Chapter 2, Cambridge Information and Research Services Ltd., Royston, Herts, 1981, pp 33-54.

8. RICHARDS, E.J., (Chairman) *Academic-Industrial Collaboration in Engineering Research,* SRC Engineering Board Report, Science Research Council, 1975.

9. WRAY, G.R., "The Application of Mechanism Theory to a Textile Machinery Innovation", Nominated Lecture of the Institution of Mechanical Engineers, *Proc. I. Mech. E.*, 1976, Vol. 190, 45/76.

10. WRAY, G.R., *Contributions of a University Mechanical Engineering Department to Innovation in Textile Machinery*, Chapter 12 of "Twelve Notable Projects — some Personal Accounts of Engineering Research in UK Universities", SERC and CEPC, London, 1983, pp 225-258.

11. GIBB, J.M. (Editor), *Science Parks and Innovation Centres: Their Economic and Social Impact*, Proceedings of Berlin CEC Conference, Elsevier, Amsterdam, 1985.

12. CARTER, N., *Science Parks: Development and Management*, Estates Gazette Ltd., London, 1989.

13. ANON, *Research and Development: Collaboration between Business and Higher Education*, Department of Trade and Industry and Council for Industry and Higher Education, HMSO, London, 1990.

14. ANON, "New Rib Loading and Gauge Units for Fully Fashioned Knitwear Production", *Knitting International,* January 1982, pp 96-97.

15. WRAY, G.R., BAKER, J.E. and VITOLS, R., *A University Approach to the Recognition, Identification and Specification of Industrial Needs*, Proceedings of I. Mech. E. Conference on "The Education and Training of Engineering Designers", University of Bath, 1983, pp 45-80.

16. ANON, *The Costing of Research Projects in Universities*, Committee of Vice-Chancellors and Principals, London, July 1988.

17. ANON, *European Collaboration in Science and Technology: A Guide for the UK Scientist and Engineer*, Science and Engineering Policies Studies Unit (SEPSU) of the Royal Society and the Fellowship of Engineering, London, 1987.

18. SATTER, M.A., DOWNS, B., and WRAY, G.R., "Reduction of Noise at the Design Stage: a Case Study of a Lightly Loaded Assembly", *Proc. I. Mech. E.*, 1969-70, Vol.184 (Part 1), pp 593-614.

19. SATTER, M.A., DOWNS, B., and WRAY, G.R., "Reduction of Impact Noise at the Design Stage: a Specific Case Study", *Proc. I. Mech. E.,* 1972, Vol.186, 26/72, pp 391-399.

20. BURNS, N.D., and WRAY, G.R., "Cam-to-Needle Impact Forces in Weft-Knitting", Part I: Theory of Stich-Cam Impact, *Journal of the Textile Institute*, Vol.67, 1976, pp 189-194; Part II: A Stitch-Cam Impact Transducer, pp 95-198; Part III Some Measurements of Stitch Cam Impact, pp 199-205; Part IV: Further Measurements of Stitch Cam Impact, pp 206-209; Part V: Guard-Cam Impact, pp 229-234; Part VI: A Guard-Cam Impact Transducer, pp 235-237; Part VII: Influences of Yarn Tension and Machine Speed on Guard-Cam Impact, pp 238-243; Part VIII: The Effects of Some Knitting Parameters on Guard-Cam Impact, pp 244-249; Part IX: Needle Latch Impact, pp 301-8; Part X: The Characteristics of Latch-Needle Breakages, pp 309-314; Part XI: The Measurement of Impact-Induced Strains in Latch-Needles, pp 315-320.

21. PAKES, H.W., PARRY, R.M. and WRAY, G.R., "The Use of Optimisation Techniques with Precision Synthesis for Producing a Planar Linkage giving Parallel Motion" *Mechanism and Machine Theory*, 1979, Vol.14, pp 171-178.

22. WRAY, G.R., PARRY, R.M., and PAKES, H.W., *The Mechanisms of a University-Designed Textile Machine*, Proceedings of 4th World Congress on the Theory of Machines and Mechanisms, Newcastle-upon-Tyne, 1975, I. *Mech. E.*, London, pp 1123-1129.

23. VITOLS, R., MURPHY, B.J.M., WRAY, G.R., BAKER, J.E., and KING, T.G., "Development of Computer-Controlled Machinery for the Making-up of Garments", *Proc. I. E. E.,* 1985, Vol.132 (Part D), No.4, pp 1178-1182.

24. WRAY, G.R., and ACAR, M., *Supersonic Jet Texturing of Yarns*, the 76th Thomas Hawksley Memorial Lecture of the Institution of Mechanical Engineers, London, 13 December 1989.

25. WRAY, G.R., VITOLS, R., and GRADY, L., *A New Method for the Production of Yarns for Specific Markets*, Proceedings of the World Conference of the Textile Institute, Nottingham, pp 205-213.

26. KING, T.G., and SIMS, R., *Mechanical Design in the Microprocessor Era — Illustrations from the Textile Industry*, Proceedings of the Engineering Design '86 Congress, The Institution of Mechanical Engineers, London, Paper 3A-03.

27. WRAY, G.R., BAKER, J.E., and VITOLS, R., *From University to Industry — Student Participation in the Innovation of Commercially Viable Textile Machinery*, SEFI Conference on "The Education of Engineers for Innovative and Entrepreneurial Activity", Delft, Holland, 1982, pp 386-395.

28. LICKLEY, R.L., (Chairman), *Report of the Engineering Design Working Party*, Engineering Board of the Science & Engineering Research Council, 1983.

29. WRIGHT, I.C., FISHER, B.C., and WRAY, G.R., *A Contract between University and Industry to further the Education of Engineering Undergraduates*, Proceedings of the SEFI Conference, Edinburgh, September 1986, pp 893-916.

APPENDIX 1 : ABBREVIATIONS USED IN THE TEXT

ACME	Application of Computers in Mechanical Engineering
ARC	Agricultural Research Council (UK)
ART	Automatic Rib Transfer
BRITE	Basic Research in Industrial Technologies for Europe
BTG	British Technology Group (UK)
CAT	College of Advanced Technology (UK)
CASE	Co-operative Awards in Science and Engineering (UK)
CIM	Computer Integrated Manufacturing
CRI	Crown Research Institute (NZ)
CVCP	Committee of Vice-Chancellors and Principals (UK)
DES	Department of Education and Science (UK)
DSIR	Department of Scientific and Industrial Research (UK; later the Science Research Council)
DSIR	Department of Scientific and Industrial Research (NZ)
DTI	Department of Trade and Industry (UK)
EC	European Commission
EDI	Engineering Design Institute (of Loughborough University)
ESPRIT	European Strategic Programme for Research and Development in Information Technology
ESRC	Economic and Social Research Council (UK)
EURAM	European Research on Advanced Materials
EUREKA	European High Technology Programme
FRST	Foundation for Research, Science and Technology (NZ)
HNC	Higher National Certificate (UK)

IGDS	Integrated Graduate Development Schemes (UK)
LCL	Loughborough Consultants Limited (UK)
MRC	Medical Research Council (UK)
NERC	National Environmental Research Council (UK)
NRDC	National Research and Development Corporation (UK)
OECD	Organisation for Economic Co-operation and Development
ONC	Ordinary National Certificate (UK)
PCFC	Polytechnics and Colleges Funding Council (UK)
PGSF	Public Good Science Fund (NZ)
RTC	Regional Technology Centre (UK)
SEPSU	Science and Engineering Policy Studies Unit (of the Royal Society)
SERC	Science and Engineering Research Council (UK)
SPP	Specially Promoted Programme (UK)
SRC	Science Research Council (UK)
SSRC	Social Science Research Council (UK; later the Economic and Social Research Council)
TBG	Technology for Business Growth (NZ)
TCS	Teaching Company Scheme (UK)
UDIL	University Directors of Industrial Liaison (UK)
UFC	Universities Funding Council (UK)
UGC	University Grants Committee (UK)
UMIST	University of Manchester Institute of Science and Technology

PART II : DISCUSSION ON STATE-UNIVERSITY-INDUSTRY LINKAGES

Guest Speakers

Dr Basil Walker
Chief Executive
Ministry of Research, Science and Technology
Wellington

Mr Angus Tait
Managing Director
Tait Electronics Limited
Christchurch

Mr John Manning
Manager, Technology for Business Growth Programme
Foundation for Research, Science and Technology
Wellington

JOHN BLAKELEY

The purpose of this afternoon's meeting is to open up the discussion wider than just the linkages between universities and industry, to include linkages between all research institutions and industry. The idea arose in my mind back in February this year when the Ministry of Research, Science and Technology organised a one-day get together at the Burma Lodge in Wellington to discuss a framework for future science and technology policy for New Zealand. One of the things that came up during the discussion at that workshop was the need to develop linkages between research institutions and industry in New Zealand, and when I knew Professor Wray was going to come and speak on a related topic I thought this was a good opportunity to get a wider audience to come and discuss this subject.

I am now going to call on Dr Walker to expand a bit on what he said in his vote of thanks to Professor Wray's lecture, and give us some thoughts from the point of view of himself and his Ministry on the issue that we are here to talk about this afternoon.

DR BASIL WALKER

Well, what I would like to do is cover much the same territory as Professor Wray, but perhaps give a New Zealand perspective to some of the comments he made, and then after that lead on into a much more specific discussion of the New Zealand situation.

One of the first things that struck me in listening to Professor Wray was the fact that we have similarities with Britain, but at the same time significant and important differences — so I think you have to look at the British experience in that context. You can't make one-to-one comparisons between one situation and another. Some of the similarities are very important. The cultural similarity is important, and that goes beyond the fact that we speak the same language. It goes into the wider cultural heritage that we still share with Britain to a large degree. I alluded to that before, in a sense, in talking about the Number Eight fencing wire mentality in New Zealand, an approach which to me is an outgrowth of the very genuine inventive aspect of the British culture, particularly in previous centuries.

But there are very important differences as well. One of the differences is that New Zealanders, despite the passage of time, still have a comparatively young, immature economy and society. I think that does make a difference. Britain, in contrast, is a very mature society and in some ways it can be argued that many of the problems in Britain are indeed the problems of great age — the fact that it has been there for a very long time. After a while cultures, I think, develop inertia simply because of the age factor. We don't have that excuse; we haven't been around long enough, so that is a significant difference.

Size is another difference – the fact that we are small and isolated compared with Britain, which is rather large. We're talking about a country of 60 million people being a small island, that's large in our terms. We are a country of 3 million people, and geographically isolated at that.

It also makes a difference in terms of the economic environment. Britain is embedded in a larger macro-economy represented, not only by the European community, but in a larger sense by the wider European community (which has now become much wider with the breakdown of the Iron Curtain) and also the trans-Atlantic community. New Zealand exists in a quite different community — the wider Pacific community — which has different markets, different attributes and so on.

So I guess the theme from all that is that there are both similarities and differences and they need to be looked at very carefully.

I would come back again, though, to emphasising the point which I keep tripping over myself, which is the extreme importance of culture — looking at why things happen or don't happen. When we compare ourselves, for example, with the Japanese and the Germans, the thing you keep tripping over all the time is the difference in culture; the difference in approach to things like science and technology, and until we can change that culture we are doing no more than addressing the symptoms of some of the problems we have. We are not addressing the root causes. Much of what we are doing in a policy sense is drifting in a direction of looking at the problems of culture.

For all of that (and I suppose it reflects the fact that we live in a very international community these days), the differences in focus that Professor Wray talked about in Britain are beginning to be developed here as well. You talked about the need to focus on manufacturing in the United Kingdom; that has its counterpart in New Zealand. Increasingly, in the science area for example, we are beginning to talk about not production for its own sake, but added value — processing in manufacturing. So the themes are there, and they are there because they both lead to improved exports which, particularly for small economies, has to be the key for escaping from the trap we are in at the moment. And added value also means, in the end, employment — people. That's why that kind of thing is so important.

Professor Wray made some very interesting comments about the way that funding structures for science and technology work, and I couldn't help grinning at some of the things he said because they are very true of New Zealand as well. It is true that funding structures, particularly government funding structures, tend to be very conservative. They tend to lean in the direction of things that are known. The things that are based on prior experience seem to undervalue things that are new and risky and hard to evaluate, and they tend to be bureaucratic. Those who have had to deal with the Foundation for Research, Science and Technology, for example, may say 'well, that's true in that particular case'. You run the perpetual risk of form being more important than substance.

It is actually quite hard to break out of that particular problem. In the end, the only way you can break out of it is to really look behind the systems, behind the structures, at the people who are involved, and try to make sure that the people get together and talk about science or technology or research in a common framework using a common language, so that you get behind the form and begin to get at the substance of what's involved.

One of the great challenges we have in dealing with the research system in New Zealand right now is that we have spent an enormous amount of time and effort — much of it not mine, much of it other people's — in setting up new structures and new systems, and in principle all of those systems and structures are eminently workable; they are perfectly capable of producing good results, but they are also capable of being totally disastrous and producing bad results. What we have to do now is look beyond those structures at the people who are going to fit into them, who are going to operate them, and make sure that, in fact, the system operates sensibly as opposed to simply being established.

Professor Wray touched on the tension, if you like, between basic strategic and applied research, particularly in the context of government funding. In New Zealand the government funding system for science and technology is much simpler than it is in the United Kingdom.

We don't have the same variety of different programmes and routes, but we do have, if you like, three major routes and they have developed in different ways and at different speeds. We have, first of all, the traditional route, which is university funding, and that is still very much the province of vote education in New Zealand and will always be the major source of government funding for research in the university community.

In the middle we have what we call the Public Good Science Fund, and that doesn't really have any exact counterpart in Britain. It is different from the Research Council funding because it has been aimed at government science institutions rather than the universities, which has tended to be the pattern in the United Kingdom. It is true that if you look at the Public Good Science Fund and the university funding, there tends to be a bias, a deliberate bias, in the direction of basic and strategic research, but that is only tenable, only survivable, if in fact there is something there to look at the other end of the system — the applied end — where the links with industry need to be developed, and that's probably the key weakness in the New Zealand funding system at the moment. To put that in perspective, I won't argue about how much government money goes into university research — you can always buy an argument by talking about that— but let me say loosely that it is somewhere in the range of $50 to $100 million dollars, and I won't argue about where it is inside there. The Public Good Science Fund probably amounts to about $250 million. The amount of money the government spends directly on supporting industry research is $5 million. So we have a huge imbalance in the funding at the moment, and certainly one of the things we are trying to address in a policy sense is the improvement of that ratio. In doing that, of course, we have (as all government departments do) very difficult trade-offs to consider. For example, there is a very good argument that we should be putting more money into the so-called Public Good Science Fund, more money into basic and strategic science, and that's quite true — we should be. Money supplies aren't infinite, particularly at the moment. What kind of priority do you put on doing that: on tidying up the Public Good Science funding as opposed to finding more money to put into industry-linked programmes?

That's the kind of very difficult political trade-off which departments like mine are involved in all the time. I think the total picture is important and there is no doubt that in New Zealand we are under-selling, we are under-rating the applied industrial component of the total research picture.

You talked about a range of methods that have been developed in the United Kingdom for encouraging not just university/industry links but, if you like, state/industry links in research. We need to use that wider context.

I think that probably reflects a particular pattern in the United Kingdom, but the same subject is of great interest here. The truth is that in New Zealand we have very few instruments available which have been put in place to do the kinds of things you talked about. I suppose to some extent that's a reflection that we have come to this as a policy problem quite late. The focus has rather unduly, I think, been on government science itself rather than on those links. It is only beginning to be picked up seriously now. I was intrigued by your comments about science parks. I would have to say instinctively that I felt comfortable with what you said. Science parks have been experimented with in New Zealand and I think if you look in detail at what is being done you will find a similar pattern — superficially perhaps successful, but if you look into them more deeply is the success real or is it indeed superficial? That is certainly not a policy that we have done anything in particular to promote at this point in time.

We are very interested in technology transfer, but there has been a very interesting policy debate going on in Wellington, particularly about technology transfer, and the debate has ebbed and flowed in quite major tides over a period of time. We went through a period in New Zealand when a lot of effort went into technology transfer, particularly in the agricultural sector. We had very major extension services mounted through our Ministry of Agriculture and Fisheries. I think that particular tide has ebbed quite substantially, partly because of the economic environment in New Zealand, partly because of the general economic environment — the feeling by successive Governments that they wanted to withdraw from too paternalistic an involvement in transferring technology, from government research institutions to the farming sector in that particular instance.

The tide is now turning, going back in the other direction, but it is turning in what I regard as a much more satisfactory way. We are now looking more broadly at the whole scope of not just technology transfer, but the whole issue of technology policy — what is the role of government in encouraging, not the transfer of technology itself, but the uptake and effective use of technology by the private sector in industry, and that is a much wider subject than simply technology transfer. It has to go well beyond the confines of farming in the agricultural sector, and we have to look at technology in a much wider context than that.

The British Technology Group you talked about is an interesting case in point. At various times proposals have been made in New Zealand for having something like the British Technology Group — a device for, if you like, standing between government, science and industry and helping to transfer technology. And it is interesting to note that the Australians are currently embarking on a very similar venture with their so-called ATG scheme.

The feeling in New Zealand has been rather against going down that path. Rightly or wrongly, I would be interested to get your comment on this later on, because of a very strong feeling — and it's a feeling that I share, I have to say — that we have to be careful about putting structures between the people doing the research, the technologist and the industries. There is a feeling here that we would be far better to do things that will put the researchers in much more direct and interactive contact with the industries and the businesses they are trying to serve rather than inventing structures to stand in the middle, and that's the direction in which policy is developing. As I said, I would be interested to hear your comments and I guess time will tell whether or not that's the right approach to take.

That approach to technology, I suppose, lies behind the approach that has been taken with the setting up of the new Crown Research Institutes. Technology transfer is an explicit part of the role of the new Crown Research Institutes, but it is a role that is built into their basic core business, not something that has been added on. And I think the hope is, from a policy point of view, that it will become an integral part of what they do, rather than something they see someone else doing for them because that seems to us to be asking for distancing between industry and the researchers themselves.

You finished by talking about intellectual property rights. That's an area I would rather not talk about. It's a very difficult area from our point of view. It's one that from a policy point of view we keep approaching in different ways and then backing off because it is very difficult. It's not just a research or science and technology issue; it's an issue that goes well beyond that. It's an issue that's becoming of considerable concern internationally. Earlier this year I was lucky enough to participate in an OECD conference on technology policy that was the outcome of a series of conferences that have been held over a period of time, and technology and intellectual property rights were a significant subject on the agenda for discussion at that conference. And the tension that was evident in the discussion was the tension between the realisation that we are increasingly becoming a global family from a technology point of view. The notion of there being a New Zealand industry in New Zealand, owned by New Zealander's and doing things for New Zealanders, is becoming increasingly distant from the international reality. It's a very mobile international marketplace and that has to be rationalised with the natural desire of different countries to have rather protective national perspectives on things like intellectual property rights.

It has, interestingly enough, been a particular problem for us in doing what we thought would be a very simple thing — renegotiating the science and technology agreement we have with the United States. It is a very simple agreement on which we don't spend very much money, but it is quite useful. But it took something like five years to renegotiate the agreement, purely because of the differences of perspective over intellectual property rights. In the end it was resolved by largely giving way to the way the Americans wanted to handle it. In essence, we had more to gain from the agreement staying alive than we had to lose from it collapsing.

So that's a very quick reaction to the things you've had to say, which I found extremely interesting. I think the United Kingdom experiences are very relevant to many of the things we are beginning to tackle in New Zealand. As I said, the common cultural background is very important because it means you can exchange experiences that much more quickly and usefully. At the same time, as I also said, I think we have to be careful of the differences between the countries and the environments in which we operate.

PROFESSOR WRAY

Thank you very much indeed for a very useful contribution. It has amplified a lot of things I probably didn't say very well. Taking your last point first, about intellectual property rights, you mentioned the United States, and it is very right that you should because American industrialists are often the keenest and sharpest. They know what they are doing, and if you are dealing with any United States company you have got to be careful on this question of property rights.

I will give you a personal experience of the North Carolina Research Triangle. I have many times been Visiting Professor at North Carolina State University at Raleigh. I am well-known there for the supersonic jet texturing of filament yarns. This is the system whereby individual multi-filament yarns — nylon, polyester — are put through an air jet in such a way that they are overfed. In other words, they are put in at a higher rate than you take them away, so as to cause all the individual filaments to convolute into buckles or coils. Then they reassemble themselves when they leave the supersonic jet so that what you have got is a 'textured' locked-in loop structure. You might think 'Who the heck wants that?', but when you think of a nylon yarn as extruded, then wearing a garment made from it would be like wearing a polythene bag. If you wear a shirt made of such untextured polyester filaments, you might think it looks like silk, but when it's woven or knitted it is almost like wearing a piece of plastic. If you somehow get occluded air spaces inside the filament structure so that the body is allowed to breathe through the textured fabric, then you have got something much more like cotton or wool. I hate to say this in wool-producing areas! You provide occluded air spaces to give thermal insulation — less lustre, better water absorption and improved breathability, so that the whole thing is attractive and in one shot you convert man-made filaments into something that resembles cotton or wool staple yarns, without having recourse to the protracted processing sequence of opening, cleaning, carding, drawing, combing, drawing again, reducing, spinning, winding — some twelve or thirteen processes. You do it in one shot!

Air jet texturing is an interesting technique. It was invented in the United States by Du Pont, but I did a lot of fundamental research on it. In fact, I did my own PhD on it. Since then I have supervised a succession of PhDs on it and I have done some collaborative work, largely with a Swiss company because Britain is not in this business. But I have also done work based on the Du Pont patents and I have lectured to the Du Pont company at Wilmington in Delaware, where it was all invented, and they said "You know far more about this process than we do". When I went to the North Carolina Research Triangle, another large company asked me would I consult with them. Now I had received no payment at all from Du Pont, or anything like that, so I was a free agent and in no way had Du Pont revealed anything to me of their process, other than what was in the patents — anybody can read and experiment with what is described in patents. So all that I had done, I had done unaided. In fact, at the beginning of my researches Du Pont tried to obstruct me working in that area. They wouldn't give me an experimental licence; they said it was "Because you are paid to teach and we don't want people to teach our secrets." That's what they told me when I first started researching in the air jet texturing field over thirty years ago.

There was no way they would give UMIST, where I was working then, a licence, so I had to do it on my own, working from the patents. But I soon got into the situation where I knew far more about the process than they did, so I didn't owe anything to Du Pont except that I had started my researches from what I had read and seen in their patents.

When I was invited to the Research Triangle to consult with another company working in the same area they met me with a form and asked me would I sign it. This wasn't just a simple form — it was three pages. I started reading Clause 1 (it was all in clauses) and immediately I said "Oh, I can't sign that Clause 1". They said "Oh, that's not meant for you". So I looked at Clause 2 and said "I'm afraid I can't sign that because that's Clause 1 again but written in a different way ." "Oh, ignore it," they said. Clause 3 — couldn't sign that either. They must have thought "Oh, a tough one we've got here". So I tore the first page off and you know I went through the whole document and there was nothing I could agree with because it would mean signing away my international property rights on anything that I had already invented or was then in my mind. Because what it virtually said was "anything you see in our organisation today, if you publish anything in future on it, we'll have your guts for garters". In other words, you are a small inventor and we are a big enough company to take you to the courts.

Some American companies are sharp cookies on industrial property rights. I never saw the inside of that factory — didn't want to either. Afterwards somebody I knew in the company rang me and said "Thank God for people like you, Gordon. There are other professors from Britain who've been through and they've signed it without reading it". They had signed away any rights they had perhaps because they were people who wouldn't invent anything anyway. But the point is that they probably don't read the small print, and I am afraid with the Americans on intellectual property they know all the small print all right. I was told that Du Pont have eight patent lawyers working away and they could crack most patents should they need to.

So many companies, particularly large ones, are very keen on intellectual property rights. This is why I have always been keen on initial contracts but you can even go wrong on this too. We thought we had a good contract with a local knitting company, who mainly made knitwear for the Marks and Spencer stores. They got us to work on what turned out to be the Loughborough ART machine — the Loughborough automatic rib-transfer process, which is directed to the automation of a knitting process for making fully-fashioned garments. What they wanted us to do was to modify their existing machines which, like many other British knitters, they had only recently bought in quantity from Germany and Italy. No sooner had they bought them than the German machine builders came out with something that made the process largely automatic, but using a much more expensive machine, double the price; it meant that all their new equipment had hardly been run-in and was obsolete in their eyes. So they said "Can you invent something that will do what the newer German machines do?" We actually invented something that would do even better than the German machine did, even though it had to be a bolt-on attachment. We couldn't do it the same way that the Germans had done: (a) because they had good patents; and (b) because we couldn't start from scratch — we had to modify an existing machine. So we invented and developed something that was, I think, brilliant for only about ten thousand pounds — that was the selling price of the conversion to a fully automatic machine.

We knew at the outset that we could do it, so the University entered into the contract and it was agreed that such modified machines should eventually be sold to other knitting companies and that the University should receive 10 percent of the selling price of every machine sold. We put in a statement that it should be based on the current selling price because we were aware of inflation going on. We thought it was all belted up, bolts and braces, until they starting paying us 10 percent of the cost of the parts that they used and not of the price they were selling the machine at. So we said "that's not the selling price". They said "Ah, but we are selling modified machines that are converted by using a kit of parts; you provided us with a kit of parts and that's what we base the percentage on".

We almost had to take it to lawyers but eventually we won. They realised we were calling their bluff and their actions might kill the goose that laid the golden eggs, as they wanted further work done. It was a measly attitude to be arguing that it was a kit of parts that we had produced and not a machine, but it taught us to beware of such attitudes. That's why I believe in really good contracts. That's where the lawyers do come in useful and you have to have as good lawyers as they have, and you have to have people who know the world of industry.

So I think it is important, if you are doing this kind of work with industry, to have a good, clearly agreed contract at the outset, in fairness to them as well as to you, and you have to be aware of the shortfalls, deficiencies and obstacles that otherwise could occur.

You mentioned BTG not being a useful model for New Zealand to emulate. The British Technology Group, in my opinion, has done fairly well. The idea of BTG is that they will exploit private inventions. They don't need to be university inventions, they can be from individuals; they also can be from the research institutions which are not universities. They can be from any source and it's just a case of whether they believe in it. They usually take any new proposal to an external referee — just like a refereed publication in a way. I've been referee for many BTG projects. People have come up with an idea that is something near to my field — for instance automatic ways of making umbrellas, a patent that was devoted to unusual ways of making an umbrella. Although I knew very little about making umbrellas before, I was soon in a position to offer useful advice.

Anyhow, the point is BTG take up external advise. Once they've agreed that they have got useful advice and they can go ahead, then of course they'll talk about taking out patent protection and they'll take patent protection through the whole world if necessary. They ask your advice as inventors, very often whether you think it's worthwhile patenting outside Japan and Europe and America; is there any need to patent in Scandanavia, for instance, or in Australia and New Zealand, and so on. You have got to give your opinion on where they should patent because it costs such a lot of money to patent worldwide. The original provisional patent costs so little, but once 12 months has gone by and you have got to take international patents and keep renewing them, then it can be a very expensive business. So BTG are providing useful venture capital in that area and, of course, there may be difficulties with the patents (as there has been on one of mine). I've got three box files of correspondence on things that have been cited in United States patent cases, which even go back to the reign of King James the First. It seems there was a man called Blodgett — I think every inventor should be called Blodgett — and Blodgett had invented a mechanism using twin sewing needles for sewing through and stitching garments together. I wasn't doing that, but it seemed that I had unknowingly used a similar technique for making pile fabrics. I couldn't have done my drawings on my patents more like Blodgett's had I already seen Blodgett's ancient diagrams. I even chose the six cycles of operations and started at the same point. I could have started anywhere, but I inadvertently chose the same point Blodgett did. He must have been revolving in his grave laughing at me, you know. And then, I beat Blodgett. I finally persuaded the patent people that my invention used a similar technique, but had essential differences and had a totally different end-use. By the way, to do it I had to tell the people in London (BTG) who had to telex in those days, not fax, people in New York, who had to then instruct their lawyers in Washington to argue it in the US patents courts.

Talk about a 'whispering game', the essential differences could easily be lost you know. Yet I was the one who knew the technology and it was going through that communication link — London, New York, Washington to the US patents courts and so on. It was so easy for misunderstandings to occur.

We weren't allowed to appear there; a US patent lawyer had to represent us in America. I don't think he put the case properly, but it kept coming backwards and forwards to us all costing the BTG money. They had to keep asking for extensions on the hearing because it went through so much communication time that it was late when it got to the people who mattered. It was already beyond the allowed time when it got to me. BTG said "Don't worry about that Professor Wray, we can pay so many hundred pounds to have it extended". So that was all money that was going to come out of any proceeds from my invention because that would all be counted against it on the final balance sheet. But eventually we got it through and then the opposing lawyer said "Ah, but if you interpret Blodgett with the teachings of Belford" — I thought "Who the hell is Belford?" That was another B, you know, and the man who was finding it all was a man called Bowler, and Belford's old patent had shown some of the things that I had indicated that Blodgett hadn't done. Oh dear!

So then I had to fight again over that one and it went on through three box files. I spent more time on fighting the patents that I did on inventing and developing the thing in the first place and I could have been much more useful in doing new research. So you can unwittingly enter this whole world of patents, which can be a jungle. It seemed that somebody in America, some patent examiner, was determined that we wouldn't get a US patent even though we had no difficulties in the rest of the world.

We eventually did obtain a US patent, but it was weakened considerably by the arguments the US examiner had brought up because only in United States patent law can you go back as far in time as you want. In British and European patent law you can only go back 50 years, and if an earlier patent is not within the last 50 years it cannot be cited against you Not so in United States law, and they were quoting British patents — that was the interesting thing. Both of them — Blodgett and Bellford — were British patents. They were quoted against us and yet their inventions were not doing the same thing I was doing; so I had to argue all that. British Technology Group did a service because they kept going, they kept me going. I think the University would have contracted out of the whole situation if it was likely to cost too much, but BTG had enough funds to keep going and they had enough confidence to keep going.

They say that only one in eight of their patents — their inventions, the things they take up — is successful, but that one success has to pay for the other seven failures. So you can't expect a lot of money out of most inventions taken up by BTG. But they do provide a good service. And I think it is a shame that this British public corporation has been privatised, because it is now rumoured that it is going to be bought by the Americans. So it means that a lot of British ideas are going to be treated in America, if BTG is indeed to become American-owned. Frightening when you think about it. I think BTG has done very well — not everybody would agree, but most people used to criticise them because they thought they should make a lot more money out of their inventions. I think that when you think of the service they gave, they were a very good institution and they certainly were a viable corporation. They were a national research and development corporation and they regularly showed a profit. They were one of the few government corporations that showed a profit.

BTG had been formed from the NRDC and the National Enterprise Board (NEB), and they were both 'quangos' doing the publicly funded things that the Thatcher government wasn’t so fond of. So they were combined together. The idea was eventually to privatise BTG and that has happened.

There is only one thing I would say against BTG and it arises from the costly international patents system. After all, the British taxpayer funded the research, the SERC research that led to the invention. It is when BTG feel that the thing is not likely to be taken up widely and then they start getting a bit concerned that something is becoming too expensive. They say, "What we’ll do, if you agree, is we’ll drop the overseas patents and we’ll just keep the British patents."

Well, you see, that’s far cheaper but what does that mean? It means that it stops any British firm exploiting it. It doesn’t stop the Japanese or the Germans or even the Irish (who are actually very good at applying things) from applying it freely. It just means that the British industries are going to be financially handicapped in any application — the people who paid for it in the first place. Interested British companies would be the only ones expected to pay a licence fee — and that seems wrong to me. It’s the way the costly patent system works, you see. It is cheaper if you just take out a patent in your own country. So you are only protecting yourself against the people you should be helping.

The other thing that I think goes wrong in Britain — and I think it's something which may have repercussions here — is when the Treasury decide how the taxpayers monies are to be divided for national research programmes. The Treasury have two main arms as regards this type of funding: the industry 'vote' and the science 'vote'. The industry vote goes through the Department of Trade and Industry (DTI), and the science vote goes through the Department of Education and Science (DES). Now, of course, the Department of Education and Science has to pay for all education, including primary and secondary education as well as everything else — the Science and Engineering Research Council and the Medical Research Council and the other research funding bodies— that is all part of the science vote. It is a big vote but it goes to education generally.

The other vote goes to industry, but research engineers in Universities are concerned with industry. In a way they are concerned more with industry than they are with science in my opinion, but certainly they only get their money through the science vote. And the repercussions of this is that one can only get at that industrial vote money if one goes along with industry.

So you, as an engineering academic, have got to get industry to take you along with them in research grant applications to the DTI. We have been taken for a ride very often with some industrial companies, where they have used our brains and our abilities, and our recent publications and so on, they’ve referred to us profusely in the grant application. We know of several cases where companies have gone so far, and then dropped us part way, and we did not know we had been dropped. They had got their DTI research money and yet they intended to do the work alone. They’ve used us, literally used us, to get that money and then they’ve done it themselves and said "Why should we pay the University?" You know?

You can be very much the poor relation of industry in going for the DTI's industry vote. And yet engineers are in that cleft stick of being between Science and Education

(DES) and Trade and Industry (DTI), and we cannot get research through the industrial money vote. It's the same in Europe, even with European Community grants now. You can't get into that European research funding unless you are going along with industry (usually with companies outside your own country) and industry again has the main say. The company can decide how much you should get, and you can be the poor relation. So even EC funding can work very badly against the universities.

You may wonder why we bother, but thank goodness some companies are better than others and these are well worth working with. But we have had the situation where we put a project up to the European Commission and we got a lot of interest in the possibility of co-operation on the proposed project from a very large Italian company making knitting machines. They said they would very much like to work with us and the whole idea behind the EC funding of research is that people in different member states should work together. But a British knitting machinery company came to us and said "Look, you have had a lot of co-operation from us; if you work with our Italian competitors you have seen the last of us." They're defunct now, so I am afraid we have seen the last of them. The point is we didn't work with the Italian company because we thought it was inadvisable, as the British Company had previously supported a Chair at the University. We had always got on quite well with them and yet we could see their objection. But it's the way the EC system works — that we had to work with a direct competitor of theirs if we were to undertake the European research. So I'm afraid we've got problems in Europe that perhaps you don't have in New Zealand. Perhaps there are some pointers, though. I don't know.

JOHN BLAKELEY

It is now my great pleasure to call on Mr Angus Tait to give a viewpoint from industry on encouraging better linkages between research institutions and industry. I approached the Manufacturers' Federation and asked if they would nominate a suitable person to come along today and give an industry viewpoint, and was delighted to hear that Angus Tait was going to come, particularly in view of the fact I know he is very busy — he is off overseas on a marketing trip at the weekend — so we are very grateful to him for coming, and I have great pleasure in asking Angus Tait to give us a few words.

ANGUS TAIT

Well, just to define the angle I am coming from: I see myself as a pragmatic technologist operating in the comparatively narrow field of industry, and the things that I would say I would inevitably say from that point of view. I have actually taken my cue from the broader title of Professor Wray's. I have included the state because I regard the triumvirate of state, industry and universities as all of very consequential importance, and perhaps in present circumstances in our country I might regard the input of the state or the effect of the state as being dominant in that triumvirate.

I should perhaps apologise to Professor Wray for not being at your lecture; I am sorry I missed it, but I do have a valuable copy of your notes. As John said, I am a bit distracted at the moment. I am away to your homeland over the weekend to sell some of the products of our technology, and for that fact I am not going to apologise, hastily adding: we need the money — New Zealand needs the money, my company needs the money and I need the money.

To the basic theme state, industry and university linkages, and a quick thumbnail of where I see us. Outside of primary produce and agricultural research and activities, the university and industry links in New Zealand have been very poor. They have been patchy and they have waned variously over the years, but they are still pretty poor.

Further justifiable criticism is that the level of research and development within industry has traditionally been poor, and that is a further constraint on the links with industry, because if there is not much R & D going on there's not the sort of people in industry who would have links with the universities. That I regard (quite properly, I think) as the outcome of the sheltered years that our industry enjoyed or, depending on your point of view, we as a country suffered from.

In the post-war years, the prospective loss of our primary produce markets stimulated the government of the day to cry to industry, "Hey we'd better do something about this", and the cry was to export for survival. And in that period of time the government stood very close to industry, they were very supportive and there was progress as far as industry was concerned in what it actually achieved, but it was from a fairly low skill base, a fairly low level of technology. In 1984, for better or worse, we got a new government who swept away much of the entrenched structures. They proceeded to lower the tariff walls, as we well know, and fairly swiftly they took what was best described as a neutral stance and said, "Let the market declare; we are not going to get involved in all of this", and much of the old industry that had been in place for some 30 to 40 years at that time, simply melted away.

In 1986 there was an interesting incident, an incident which I keep the outcome of on my bookshelf because I think it was a significant document. The government of the day commissioned a report on science and technology from a group that was chaired by David Beattie, who was Governor-General at one stage, and the title of that book was *The Key to Prosperity*. It recommended various supportive measures from governments — primarily identifying technology as the prospective driver or the engine of our economy, as was quite evident in the emerging countries, particularly emerging Asian countries. The government was outraged, in fact they publicly pilloried the document, simply because it was contrary to the government dogma of the day and all that this Committee said was "technology can be the engine of the economy, but it needs the support and encouragement". I think that was a very sad incident because it displayed clearly the attitude, the indifference and the ignorance of our political masters of that time.

By the end of the 1980s, New Zealand was in a pretty bad state. It had been suffering the trauma of the violent changes of the preceding six years. We had gone through the sharemarket and the property crash and it is not too fanciful to paint a picture that we were all affected by the stench of the rotting corpses of the sacred cows that have been decapitated in that period of time. We were in deep recession, so it was a pretty miserable spectacle by the end of the 1980s. What was left of industry was in a survival mode; and a survival mode is not the stuff of enlightened conversation with universities. The linkages at that stage didn't look good.

Over the same time frame of about 20 or 30 years, industry/government relations fluctuated wildly. They fluctuated in the 70s from warm support from the government of the day to industry, to the indifference of the succeeding government, and that indifference was, I believe, born of prejudice and ignorance.

In 1989 — and, in fact, to sort of cap that and highlight that state of mind — the government of the day actually abolished the office of the Ministry of Industry.

And what they were saying, as far as I was concerned when I became aware of it, was that industry in this country simply didn't have a place, we didn't rate. I felt that was a pretty grim compliment for any government to pay — or not to pay — to the little bit of industry that we did have. So these linkages simply didn't exist at that point in time between industry and government.

So here we are now, a couple of years into the new decade. The holocaust has passed, we have buried our dead (and there were quite a few of them), and the survivors are counting the cost. In reality it is not all bad, and I am saying that from a sense of fair play. We have a depressed economy, but we have a very stable economy. We have very low inflation, we have got admirably low interest rates and we have a stable labour force structure, and that mix is the stuff of competitive edge in the international trading world. Furthermore, there is a new industry emerging and they are far different in character and quality from that which was consumed in the holocaust. They are better informed, they are better equipped. In my own narrow segment of industry, for example, there are three times as many graduates now employed as there were in the old industry, poorly informed and inward-looking that it was.

The most impressive feature is that there is a recognition that future prosperity lies in export. There is also a recognition that that means working to world standards. So finally, the myth has, I believe, been put to bed and that myth is the one that has been promulgated in New Zealand for a long time — we can't compete with the Japanese or the Taiwanese or we can't do this and we can't do that, and of this sad spectacle of a little country with people trying but feeling quite inferior with respect to what is being done and what is being achieved in the rest of the world.

In simple terms, what has emerged (and what I firmly believe) is that if the design is right —and that is from concept right through to production — we can make it here and we can sell it anywhere. Such is the stuff of competitive edge. I believe that it is well-demonstrated that this is factually correct, in that there are a number of visible successes, but too few, far too few. We need a great deal more to regain the strength and the position that we have lost in our economy through the effects of the destruction of the old industry.

Our government maintains, and I think it is fair to say a little hysterically, that it will all now happen: everything is going to come right — the environment is right. They've done those things which I quite agree with, but they are saying in effect "Hey presto!" They're waving the wand and it's all going to happen: industry will multiply, jobs will be created and, of course, they will be back in power next year. I think all of us in this room wish it was so — you mightn't wish the last bit so much, but we wish it so that all would come right. But I think that is a bit simplistic. I think it has been well demonstrated in many countries that the creation of new industry, new jobs, is a slow process unless stimulus, initiative and encouragement by government is part of the total package. But here's the rub: our government won't have a bar of it. It is dominated by dogma. They display supreme indifference. Their motto is almost "Please don't confuse us with the facts; our mind is made up".

There are other words you could use, words like 'arrogance' — take your pick, there are a whole host of words, but they are in power at the moment. But, as ever, I believe the electorate will decide. We do, finally, have a democratic form of society and I believe that it must follow, as the night the day, that unless things come right we will have other masters. But whatever happens — and what I mean by that is whatever masters we have — I firmly believe that some government not too far down the track will take a more enlightened view, they will stand closer to industry and they will introduce much more enlightened policies in respect of industry policy, much more enlightened policies in respect of the Government's working relationship with industry.

Until that arrives, until we have that changed attitude, I believe that the growth within industry — this new growth that we so desperately need — will be slow. It will be slow to heal the wounds that we are visibly suffering from, from the days of the holocaust. To be fair — and I have a strong sense of fair play in me — there have been useful things done and there are useful things being done.

The funding for science and technology has been maintained despite the grim financial position that we are in as a result of the events of almost the last decade. There is direct financial assistance to industry. We are into research and development through the Foundation for Research, Science and Technology. It is a small fund, it was mentioned as being of the order of five million dollars. We in industry are grateful that it has been done.

There is a small cynic inside of me, of course, that says, "But hang on a minute, this is the government that refutes entirely the concept of picking winners, but what are they doing? —they're picking winners, they are saying 'That's a good thing, we'll give you some money' and they give out the money". I argue that they should lend the money, but they give the money. They isolate. I have personal knowledge of this — that reasonable sums of money are being given to specific prospects who are, in my simplistic view, 'winners', they are identifying or causing to be identified as winners. I think it is a great thing and I think it's a pity that the fund isn't 50 million dollars. I am comforted by the statement from the Beehive that, in principle, some people in the Beehive wish it was 50 million dollars as well, but we haven't got the money, so I think it is fair to identify that as being a commendable act.

There are some government agencies that are trying hard to improve the lot of industry. The old Trade Development Board, or Trade NZ as it is now known, is putting considerable effort into pulling industry groups together and instilling some sense of direction into industry. That is good stuff and it is to be commended, but it is not anything like the level of thrust that is required if we are going to achieve what we so desperately need to achieve in terms of our ultimate standards of living.

Anyway, what's this tirade got to do with linkages? I believe it's simply this: the government to industry links are almost nil, distanced by dogma, which is most regrettable.

University and industry links are in a more healthy state and they are improving. A better class of industry is growing around us with more graduates and a greater appreciation of the importance and the significance of the working relationship between industry and the universities, but we still have a long way to go. It is not unreal to liken the relationship between government, industry and the universities as a strong three-legged stool. We don't have such a device. Others do, and they are visible from where we sit down at the bottom end of the world. We look to Asia — there are many strong three-legged stools in that part of the world and I believe we as a country, as a nation, are the poorer for the non-existence of that three-legged stool. Given a government standing closer and a longer leg resulting, then closer links would emerge from that.

Growing prosperity within industry must secure stronger and more secure university links. Prosperity within industry is an essential part of the success of industry; it's kind of fundamental, but I believe it is particularly significant in relations with the university. A prosperous industry is the sort of industry that has the will, the mechanism and the means to stand close to industry and I think that has been well established, traditionally established in the old world. I would be personally delighted to be in a position in my own company to stand more closely alongside of industry and alongside of the university, given the sort of long-term prosperity which I believe we can and should achieve.

In all of this, I don't think I am alone in these views. In February of this year the Ministry of Research, Science and Technology ran a workshop in which we debated research, science and technology policy development. There were 30 to 40 people there drawn from industry and universities, some of the state enterprises and from government, and from the notes that were subsequently published of that day's discussions I'll highlight some of the points and issues that were raised at the various workshops and I'll read them straight from the document.

Of the issues and various complaints, the first one I note is that there was no shared strategic vision between government and the private sector.

The second point was that the emphasis of government investment is in science, not technology and business development.

The third was a lack of good understanding of technology in society, which bears on the point that was made about the culture that we so sadly lack in our country. I suspect we are not alone in that. An issue that springs from a common problem in the relationship between industry, particularly, and politicians, I believe, is that there is not a good understanding of the place of technology — the potential for wealth and energy and power that can be derived from a strong technological base. This has been well said in the phrase I like the best: that technology is potentially a strong driving engine of economies. This has been demonstrated time and time again in the post-war world.

Another point highlighted that day was the recognition that technology (exactly as I have been saying) is an essential driver of the economy. And the last one of the goals: to establish a pro-active partnership between industry and government.

I read those out simply, not really in a defensive mode, but to highlight the fact that there is a strong body of thought within the thinking people and the decision-making people within our country. But some of the things that I have highlighted in what we have said so far are not wholly outrageous and they find common ground. So, government attitude is the key, not in the spirit of the jibes which I find most distasteful from our government. Whenever the subject of government relationship with industry is raised, the response from government is in a jibe-like form. They refer to the era of the 70s when there was strong government support of industry. They display no interest in what's been achieved in other countries now in respect of properly supportive and properly assisted government activities, but dismiss it out of hand as being entirely inappropriate.

So, to sum it all up, I am an incurable optimist — I would be dead if that was not so. I do firmly believe that it will come right, but not in a mysterious, magical way. We in industry have got the wit and we have got the will to play our part. I believe that some governments down the track, and not too far down the track, will do the things that government has to do to put the thing right. Universities, I am sure, will understand the opportunity and seize it, and I believe quite confidently that we will have our three-legged stool.

Thank you.

JOHN BLAKELEY

Now I saw Professor Wray writing a couple of notes down there. Would you like to just briefly comment on those?

PROFESSOR WRAY

Thank you very much. I agree with what you said, but I don't think I'd liken it so much to a three-legged structure because I am a mechanisms man and I work in the world of linkages. Mechanism is a combination of linkages, and a linkage becomes a structure when you remove one degree of freedom so your analogy meant more to me when you mentioned the engine, the engine of change. Now the only three-part mechanism I know is an engine and it has served people well over the years. We all came here using an engine incorporating a slider crank chain. You have a crank, a connecting rod and a piston, you see, and really that's the engine of change. That provides the momentum and the power. I don't know which parts correspond in the analogy I mean obviously the university would be the crank because there are enough cranks in universities! Perhaps the government could be the connecting rod and certainly industry should be the piston.

ANGUS TAIT : But we haven't got a connecting rod.

PROFESSOR WRAY

Yes, that what's you were saying, so it's not much of an engine is it? There are some engines without connecting rods, but at the same time, as a mechanism's man I see this engine of change as very much a linkage — state, industry, university linkages. You have commented about the problems with government. I wonder if you in New Zealand are in the same position that we are in Britain. How many graduate engineers, technologists and scientists are in your Parliament? Not that it always does all that much good, because we've had a Prime Minister that was a scientist and the university science suffered badly under her. I wont mention her name so you won't guess who I'm talking about. That was the reason she was refused an Oxford honorary doctorate. Prime Ministers who have been educated at Oxford usually receive an Oxford honorary doctorate, but the Oxford community refused to give her one because they did not agree with what she had done to science and education.

So does it do any good to have scientists up at the top? On the other hand, I believe there are only three engineers in our Parliament in Britain and they are in very lowly positions. There was only one engineer near the top and he only served in a minor ministerial position in the last government.

What sort of people do you get leading you? Do they understand the meaning of effective links between universities and industry? I think it's up to us to get more people into Parliament who have been taught the common language of industry co-operating with academia. Much is wrong with academia as seen in a lot of attitudes, as I said before: engineering scientists training their own kind of engineering scientists, educating the wrong kind of engineers for industry. I know one thing, that at our university at Loughborough there is not one person lecturing in the Mechanical Engineering Department who has not been in industry. Not many universities can say that, but we always insist that we appoint people with industrial experience, because we are a University of Technology and we are educating engineers to serve at the cutting edge of industry, we are not making engineering scientists who become "back room boys".

But even some of these industrially reared engineering academic staff become scientists because they are made to toe the line, you know, play the publications game. To look respectable and get promoted they become scientists. Don't get me wrong, I am not against science — I am a Doctor of Science and I am a Fellow of the Royal Society. I am certainly not against science, but at the same time I am all for the *application* of science and that is surely what engineering is all about

ANGUS TAIT

We have this problem, of course, with politics as a career — the image of which is not being improved in recent times.

Perhaps if I make you aware that the *National Weekly* newspaper conducted a poll recently of 500 people or so, and the simple question was "Would you rate the following persons in accordance with the images that you see" and it went right through the professions — the police force and used car salesmen and politicians — and, sad to relate, but published on the front page of this national newspaper was the outcome.

And the sad aspect was that politicians were second from the bottom, only a little higher than used car salesmen, which while we all laugh, is really very sad because events of the last decade or 12 to 15 years have created this cynical impression in people's minds that politics is not a particularly reputable profession. And maybe there are no admirable and pragmatic engineers there because they have looked at the calibre of people that ***were*** there and said "I'd rather not be with that lot, thank you". My tongue is a little in my cheek, but sometimes when the tongue is in the cheek there is a measure of truth about it.

UNKNOWN

Just to comment on the last point, the one about politicians and so on, I don't think it's actually particularly important to have scientists and technologists in Parliament as politicians. What is important is that you have a group of politicians who are science and technology literate and who are sympathetic to why those things are important.

There is some disadvantage in having people who are professionally qualified. For example, it is well-known that the worst Minister of Education you can possibly have is someone who was once a teacher. I mean, they are terrible as Ministers — they think they know everything and they won't take advice. It's much better to have someone who is intelligent, hopefully, but who is aware of their professional deficiencies and is therefore willing to listen and take advice on how the portfolio should be run. I would say that the present Minister of Science and Technology has probably been more effective than any other Minister of Science that I have certainly had any connection with, and he is not a scientist. He is intelligent, but he is certainly not a scientist and, therefore, he takes advice.

The real gap to my mind is not in the Beehive, it's in the boardrooms of the country. We have far too few scientists, technologists and engineers sitting on Boards of Directors and at senior management level in companies. If you look at the average Board in New Zealand compared with, say, Germany and Japan — and I think Britain probably suffers the same problem — but it's true, you find that there is far too high a proportion of accountants and lawyers, and far too few scientists and engineers. I think it has to change and it is gradually changing.

PROFESSOR WRAY

But then government has got to come in, surely because how long are they going to think that we can educate our engineers to take those high responsibilities and still only give them three years education. You wouldn't give a doctor three years education and expect him to operate on people; no they give him at least five years of education. Yet you are expected to bring in all this extra stuff for the education of the engineer and we want more microprocessors, more design, more management, more cultural studies, etc, all in an already overcrowded time-table.

I was talking to a Professor of Philosophy here. He said "Why don't you have more philosophy and ethics in your engineering course? What do you knock out? Do you knock out thermodynamics, stress analysis, mathematics? Could he tell me what to knock out and stop these people working, doing nothing except studying all around the clock? Engineering students seldom enjoy University life as much as the other students do because they are so tied down to examinations and passing in such a wider range of subjects. The midnight oil is constantly burnt in the engineers' bedrooms on the Loughborough University of Technology campus.

The government ought to be saying, "Well, it takes longer to educate an engineer — the Germans take six years, why do we only take three in Britain?" (Four, perhaps, in New Zealand?) But it is not long enough to teach all the things that they need to know to make good managers. How can they be good managers when they've had to have so much engineering detail crammed into them? And so who become the managers? Who indeed become the best managers in the university? The people who have plenty of time at university — more coffee breaks, lesser lecturing loads — you know, the economists and social scientists, the people who can whip up university politics, who can really get their share of the university money because they plan it well and they go in as a well- orchestrated team into Senate and so on. I've seen it, haven't you?

The engineering lecturers are too damn busy with the real needs of engineering industry and the underlying advanced technology to know how to match those people, and that sort of mentality gets through to our students. They are not trained to be good managers and it's not obtained by giving them more lectures from many of the existing management lecturers, because some of the people teaching management at universities couldn't manage anything; they can't even manage to draft and mark exam papers. You know it's true. And so I am very keen that there should be longer engineering courses and we should get all the necessary extra management skills taught within our education system so that graduate engineers can manage their own industry and not leave it all to the lawyers and accountants.

ANGUS TAIT: But you know it is partly the fault of the engineers themselves.

PROFESSOR WRAY : You are saying that.

ANGUS TAIT

I can say that because I am an engineer too, but that's one reason why engineers aren't too successful when they get into Parliament. You talk about the real world being the one that engineers deal with, but in fact there is a bigger real world that you have to deal with whether you like it or not, and it is a real world that's populated by people like politicians and lawyers and accountants who don't understand and aren't interested in things like engineering. So if you want to be successful you've got to be prepared to dabble in that world, because that's a real world as well. That, I think, is one of the problems that engineers have professionally in that they want other people to come and meet them in their world without being prepared to go out and interact with that wider world.

PROFESSOR WRAY

The engineer is at a disadvantage in that the lawyers and all those other professionals you mention, haven't they had more time to study the wider philosophical qualities because that's mainly all they've done? Most have done no real mathematics, they've done little physics, they've done none of the sort of things that the engineer has to face up to in his three limited years, so they have been educated to succeed in that more glossy wider world, that somewhat superficial world that typifies Britain and Australasia. It's not superficial in Japan and Germany — the real world there is producing things that aid the national economy and their people recognise it. To have the title "engineer" in front of your name means more than many of the other professions and you get paid more. Again, I am afraid its this business of culture. In Britain we've got the "Yes Minister" culture, the Sir Humphrey culture, the "gin and tonic set" who know "bugger-all" about the real world of engineering that produces the wealth that keeps them in jobs.

JOHN BLAKELEY

This is probably a good note on which to ask John Manning to say a few words. John is here from the Foundation for Research, Science and Technology and he is manager of the Technology for Business Growth Programme. I offered John the opportunity to speak about his programme, but perhaps also, more broadly, about the Foundation.

JOHN MANNING

Well I think most of it has been said. I actually agree with most of what Professor Wray has said, especially about the class mentality about different professions and that the technologists and engineers are seen as a lower class than the accountants and the lawyers — and that's a very significant cultural problem in British-based colonies, as I call them. We are trying to fight battles on a smaller scale than that and our attempts at changing the culture of New Zealand industry relate to just trying to convince them that it's worth spending some money on research, regardless of how they think of research positions and research staff. We would just like them to spend more on research projects and developing new products, and so we provide some assistance to start them off in this line.

Our programme's probably a mixture of quite a few of the programmes that you have already mentioned that exist in Britain, and is probably most closely related to the teaching company idea (and I hope we are going to do it well enough that it succeeds). You seem to indicate that the teaching company system in Britain hadn't succeeded too well. We, at the moment, have had quite a few projects and we have products that are succeeding in the marketplace.

We insist on companies involving themselves with government research institutes, including universities, and the reason for that is to ensure that the company has a reasonably high standard of research skills to make use of. One of the difficulties we face in that area is that there are a lot of companies in New Zealand that don't trust academics. They don't trust them at all. When we impose or try to impose this government/institute partnership on them, they view academics as being unlikely to achieve goals on time, unlikely to achieve them within a budget and very likely to disclose trade secrets to other people. It only takes one example of this to taint all the universities and Crown Research Institutes in the whole of New Zealand — which is unfortunate. But that mistrust is, from my experience, a load of rubbish. Having worked both in industry and for universities and the DSIR, I can see it from all sides. And with a lot of the company managers, that mistrust comes from ignorance and nothing else; they don't have any experience of the university and DSIR systems.

On a brighter note in New Zealand, we are still blessed with the most unqualified inventors, like those you mentioned from 200 years ago in Britain. I don't know if you've still got them in Britain, but we definitely have them in New Zealand. They are a very bright spark in New Zealand technology, and a perfect example of this is a company in Hamilton called Power Beat International. They have reinvented the leadacid battery and they are probably the first people to make a significant redevelopment of that technology since it was first put together — and that invention was done by an ex-policeman. I think he got UE, I know he got School C and he might have UE or roughly equivalent of A levels and nothing else, and his invention is considered valuable enough for Mitsubishi Holdings to have given him $750,000 for an eight percent shareholding in his company. So we still have that in our favour and we just have to pick them up and run with them now.

JOHN BLAKELEY

John, this morning you mentioned two other possibilities that may be coming up for TBG to encourage technology transfer and to offer assistance in the development of inventions. Are they able to be talked about or are they still very much under wraps?

JOHN MANNING

Well, this is the paper that Basil's Ministry has put forward to extend the Technology for Business Growth programme. We are looking for extra funding to allow technology transfer directly from the government research institutes, including universities, where assistance can be given for the development gap (I think you called it), so that we can fund the turning of technology into a prototype and it can then be sold. It's no good trying to sell ideas, I've tried to do it personally and on a private basis — go out with technological ideas and business plans and try to sell them, but no-one will have a bar of it. But if you take a prototype or an example to someone and wave that in front of them, then they react and that's hopefully going to fill that sort of gap. The other arm of the scheme is to allow industries to develop products without necessarily having an Institute involved with them. This is just a political balancing act, I think.

UNKNOWN

Perhaps I could add a bit to that too. Yes I think, as you say, what we have done is taken the original TBG programme, which was originally developed by DSIR essentially, and we have added extra legs to it to make it a more comprehensive approach to looking at the industry end of the whole science and technology picture. All the policy development work has been done. It's all there, it can be put in place, but it's meaningless without some funding, basically, so it's on hold until we can crack that particular part of the problem. There was no prospect in this year's budget. We were hopeful, but maybe things will be different next year.

JOHN BLAKELEY

Well, you won't have all the establishment costs for Crown Research Institutes, hopefully, next year.

UNKNOWN : Well, there is an election coming next year too.

JOHN BLAKELEY

At this point, I propose that we break for coffee for about 10 minutes and then there will be an opportunity for general discussion or for anybody who would like to put a particular question to any of you people who are on the panel.

(John Blakeley resumes)

It is my Chairman's prerogative to kick this off with a subject which I am particularly interested in, and which was touched on in Professor Wray's lecture this afternoon: the disincentive for academics to be involved in active collaboration with industry because it could prevent them from publishing papers if the subject is commercially sensitive; and the fact that promotions committees within universities seem to rely very heavily on lists of published refereed papers and journals. It doesn't seem to be all that clear whether they take due note of how good the journal is, as long as it's been published in some acceptable journal.

In relation to achievements by academic staff members in other areas — in particular, with relationships to industry which seem to get no credit whatsoever — I chaired a group which was set up by the New Zealand Vice-Chancellors Committee in 1986, as a result of representations made to the universities by the New Zealand Manufacturers Federation that they needed to look more closely at linkages between universities and industry. This working party (which is still in existence now) came up with a report to the Vice-Chancellor's Committee, and one of the things it touched on was this issue of promotions policy in universities. We made some recommendations that this should be looked at, but the reply was, of course, that every university has to make its own decisions about what its policies are in regard to promotion. But it seems this is a real problem and it is getting worse, and I would be very interested if anybody else would like to air a view on that particular matter, in addition to which the floor is now open for any other issues that have been raised in the course of the day.

First of all on this promotions one — would anybody like to sound off on that?

UNKNOWN

The people who are responsible for making the promotions, presumably they got to that level of responsibility through the existing system and therefore they have a vested interest in retaining it.

JOHN BLAKELEY

I think it is also an issue that promotions committees are often dominated by people who come from the Arts Faculty or pure sciences, and they are trying to fit the criteria for promotion of engineers to the same kind of criteria as might be appropriate in a very esoteric arts subject.

UNKNOWN

Mr Chairman, I don't think it is a matter between arts and engineering, I think it is a matter of academic culture, especially around this University — a perception of the Cambridge of the South Pacific and the sorts of things that you are talking about and what Gordon has been talking about are not valued as being part of that culture. You don't get Brownie points for solving the problems of Angus Tait. It is as simple as that.

PROFESSOR McCALLION

I've been on the Promotions Committee and I have represented the views of the Department to the Promotions Committee on many occasions on whether they take publishing in the *News of the World* or the *Sun,* or whatever papers now exist, into account as compared with *I. Mech. E Proceedings*, the Heads of Department are quizzed quite closely on what they regard as the value of the papers, so that I think the Committee tries to get a fair view on that. I have no hang-ups on that.

What I find difficult is that year after year I make the case on design and what is said to me year after year, and I go back to the Department with it year after year, is that if there was a public statement, if there was something in the public arena that could be judged in terms of design in the same way as a piece of research published can be judged by the peer group, then there would be something for the Promotions Committee to consider.

You see, we are not the only ones in this University — Fine Arts, someone who does painting or sculpting or something, they are in the same boat. And their painting, if they can put on an exhibition of paintings, particularly if it is reviewed in a reputable journal and so on — and so what the Vice-Chancellor has said on numerous occasions is: "If your people could work out a way in which their design and development-type work could be put in the public arena and commented on in this same way, judged in the same way, then that could be taken into account." But it isn't quite so easy as that because we don't do full designs, we just do bits of designs.

JOHN BLAKELEY

There's an even greater problem with consultancy, and that issue was touched on in this working party back in 1986 and quite a few people were of the view that you had to take your credit either by a fee for the consultancy, or if you were doing the research you got your credit through promotion. Now I think, in fact, many good academics are also in demand for their consultancy services and I don't see any reason why being in demand as a consultant shouldn't be a criteria for being promoted.

UNKNOWN

One possible thing that may be put into the arena, you know, from the research administration point of view — and I represent that from Massey — is that the assignment documents on patents and patents being the most refereed publication in the world. There is a clause in there that says the University has to give back the dollar and, of course, given administrative greed and all these sorts of things, sometimes this doesn't happen.

So what we decided to do was to create a certificate. If it's endorsed by Council with the Council seal on it, it says this person has assigned this invention to the University and there is a ceremony planned for later on this year. A luncheon with the University Council which essentially parades the inventors, so there is an idea that Council's endorsing the assignment. They know of the assignment anyway and it creates an atmosphere where our inventors within the University are being looked at and endorsed by Council, and what they do with the certificate doesn't really worry me, but the fact the University is seen to be supporting these types of people, we have formalised.

PROFESSOR McCALLION

John, one other point is that we are in a vicious circle at present because it is very difficult to attract working engineers to come back into academia, because they are likely to have to take a substantial salary drop to move back into the University.

If they are persons with ten, fifteen, twenty years experience, but not a significant publication list, they cannot get into the University at, say, better than the lower part of the Senior Lecturer's scale, and it tends to perpetuate the University Engineering Departments as being staffed by pure academics, which is neither a benefit to the students nor the sort of long-term value of those departments to the public.

PROFESSOR WRAY

On that last point, I should mention the problem I've got in the Engineering Design Institute (EDI) of getting new staff. I was given three probational lectureships to start up the institute. Now there is no way an engineering design institute can start up with pure academics. We could not have been successful if we hadn't had people who knew the real world of engineering and the engineering industry. So I had to find people who had been designers and knew what design was all about, as well as being sufficiently talented to teach graduates how to design.

One probational lecturer was a young man who had worked for a company on robotics relating to North Sea oil rigs and based in York. He was persuaded to come back to the area having been educated in the Loughborough area previously. To join us he had to try to sell his house in York and bring his children and his wife to Loughborough schools and uproot himself for a three-year probationary appointment. Just imagine the uncertainty of this family movement always hoping his job would be made permanent.

Right, the three years is nearly up for him; they are looking critically at his case. Yet, partly due to his skill and effort the EDI has moved from zero students to 100 Masters students on his course — 100 Master of Science students, 60 from industry, 40 full-timers — can you imagine it? They've all got individual projects from industry and he has to supervise these on top of an intensively heavy teaching load. He sits there with the students (either individually or in small groups because design is caught as much as taught), sits there at the computer graphics terminal with them or at the drawing board until really late at night, his wife and family wondering where he is — you know, ringing up: "I'm coming home in a minute dear". That's it and he is constantly working like that, he's one of the best teachers we've got.

So the University people are saying "This man has written no publications all the time he's been here". So I have to make the case. I know if I ask the students what he's doing what the answer will be. Tremendous job; we can't lose him. So the University says "Oh well, we'll give him another year's probation but he had better produce some papers by then". What's going to happen to beat the system is that when I get back I'm going to have to write some papers with him. But I shouldn't have to — I shouldn't have to do that but I want to see his appointment confirmed.

There we have an excellent teacher, one of the people who the new Institute is really depending on, and all the University hierarchy is saying is "Where are his publications?" If he doesn't publish he will be damned because his probationary appointment will not be confirmed.

Its easier to publish in other fields. Two economics lecturers came to see me (when I was Head of Mechanical Engineering) and they said "You run a sandwich course, how many students do you have on it? How many are industry trained? How many this and how many that?" I gave them all the statistics, then I found out, when I looked through their 'refereed' publications, that they had written three papers based on what I had given them. I mean we in the Mechanical Engineering Department didn't think it was worth publishing; they were just number crunching to argue about the value of sandwich courses. Then their work was quoted against us by government bodies set up to disestablish sandwich courses on the grounds of cost. That is the sort of thing that happens.

BASIL WALKER

Certainly many of these problems are problems inside the universities themselves, aren't they? I mean they are ones that, in theory, you can fix yourselves?

UNKNOWN

Well, they certainly vary from university to university. Certainly at Lincoln they make a specific case of taking account of the value of the contribution — whether it had been in the form of research papers or in teaching or in community activities.

PROFESSOR WRAY : How do you take into account the teaching?

UNKNOWN : By assessment.

PROFESSOR WRAY : Who is assessing them — the students?

UNKNOWN : Oh yes, the students.

PROFESSOR WRAY

You have student assessment? Oh well, that's something we've not been able to bring in. The Americans have that. I think we should have it in Britain.

UNKNOWN

With the individual contracts you can write a performance agreement between the boss and the university academic that says what the boss wants from you. If you agree that it's going to be papers let it be papers, but if it is something else let it be something else, so much more sensible from what I can gather.

PROFESSOR WRAY

This resistance against asking students to assess teachers is usually by the those individuals everyone knows are bad teachers. They know they stand to suffer by it, because it gives the students the chance to say publicly what they have said privately to me as Head of Department. One lecturer was supposed to have said to them when they asked a question in first year: "If you ask a question like that you shouldn't be at university". Well, what sort of an attitude is that? Are we seeking after knowledge or not? He puts them down like that, kills their motivation. Yet that person is dead against student assessment of his teaching because he is known to be such a bad teacher. He advanced to a Senior Lecturer because he performed in the RAT race — Research, Administration and Teaching — in that order. Do research and you ascend on high; do administration and that will help as well; do teaching and who knows? — anybody can teach they say. So we don't assess teaching I'm afraid.

JOHN BLAKELEY

Basil Walker has commented that perhaps this is within the realm of the universities themselves to put right, but the problem, as I see it, is that some universities seem to have the attitude that if — as was said in a lecture —with the cultural thing, that if you're doing work of real application, well that's not really sound academic work and therefore it doesn't belong in the university. Now that attitude is quite prevalent in English-speaking countries.

UNKNOWN

A similar thing is occurring to some extent through the FRST funding, from the Public Good funding, where the academic, pure research is favoured over the applied research.

Within a background of industrial CRI we were frantically writing bids that were not to look applied, that had to look not useful, because we just kept burning our fingers as soon as it was applied. So you've got this gap, but the gap actually has two forms: one is where you've got an electronic idea that you take through to an electronic prototype and then you take it through to an electronic thing that gets sold in industry.

There is another type of gap which I think contributes to the lack of uptake of agricultural research. A lot of money goes into producing a specification on how to grow a plant, a new species or whatever, and that's all done within a particular institute. There is then a quantum step to do the engineering to enable a farmer to deliver on that specification. So it's no longer a lineal process like a small electronic getting bigger and bigger and bigger, but agriculture, agriculture, agriculture jump into engineering and take the next step to make it work in the fields. And to me that is a step that is not well managed through, say, the PGSF funding. If we as, say, agricultural engineers apply for funding for that sort of pre-development bit, the engineering bit, they say, "Well, you go to the agriculturists and work under subcontract to them". But their job is to design a new specification for a plant. So this sort of pre-development gap that's missing does take several forms, and I am wondering if you've got any comments on that.

PROFESSOR WRAY

Pre-development gap. I have merely seen it in the design of machinery, the gap between research and its industrial application, but you think it happens in developing things in a wider context? Is that it?

UNKNOWN

The research process that goes down this track, and we've actually got to take a different technology to add to that to make it useful to the farmer. And to get those two technologies together is a very difficult thing to do.

PROFESSOR WRAY

Yes it is and how are you going to get credit for that in the publication scheme?

UNKNOWN

It's always been in this area that the agricultural engineers simply doing the blue overalls bit to help the smart scientist who developed the new plant species. When, in fact, it is very sophisticated design engineering required to get a seed exactly 12 mm below the surface when you're driving through tussock this high with rocks this big.

PROFESSOR WRAY

Oh yes, I see what you mean now. Well, to me, that's very much a design problem and design never involves only one discipline does it? To me, design is inter-disciplinary and that's the beauty of the Engineering Design Institute and that's what I find exciting about it — the fact that we're involving the whole University, even the Economics and Social Sciences and Human Sciences — because design is an activity that involves everybody when you think about it, certainly the human scientists — the man-machine interface is crucially important. Your problem of inserting cereal seeds precisely in the ground is a good example. I've done some work on that and I know that it involves more than one discipline.

One thing satisfies me most of all. I've managed to get the University going with me on the only thing on the campus, in my opinion, that's really interdisciplinary and that's the Engineering Design Institute. But I'm afraid that even that is under threat because, even though it's the Vice Chancellor's blue-eyed baby — he really thinks it's good; he knows it's good, but it's not yet producing mounds of research papers, you see. They've got the national research selectivity assessment coming round again and they're looking for research papers from the Engineering Design Institute because it is judged as a separate cost centre externally and on the campus. And so to hide it from the scrutiny of the conventional scientific types who externally assess the research record for future funding —you know, the sort of people who only recognise excellence by numbers of SERC grants, PhD students and refereed publications — he feels he has to move it into a Department, and he's moving it into Mechanical Engineering (where I came from).

And so people are saying to me, "Gordon, I believe the Engineering Design Institute is going back into Mechanical Engineering", and I say "Well, for a start, it never was in Mechanical Engineering — I was in Mechanical Engineering, but the Institute wasn't — and it's not going back into it, it's going back into it only as a cost centre." But it's very hard to argue that. Just as a cost centre it will be costed under Mechanical Engineering, but if on the campus they see it as going into Mechanical Engineering, what chance has it of appearing interdisciplinary? At present it's seen as a separate entity and the students that are coming on the course are not only mechanical engineers. They aren't coming to learn mechanical engineering design. They're electrical, chemical and civil engineers, they're scientists, they're physicists, they're mathematicians, they're even managers, they're architects — all sorts of people are coming on the course to do engineering design because it's interdisciplinary. We're all collaborating in this interdisciplinary atmosphere, but as soon as it's seen to be part of a single-discipline Department, that's the other cross I'm bearing at present. One is the earlier mentioned young probationary lecturer syndrome — and trying to get him kept at the University; the other one is to stop the Design Institute being seen as part of a single Department, because as soon as it's seen as part of a single discipline it's no longer seen as interdisciplinary.

UNKNOWN : Is it contributing to industry/science links in its present form?

PROFESSOR WRAY

Of course it is, very much so. I mean, every individual design project is set by industry and **50 percent** of our students are part-timers released on a modular basis from their employment. government isn't involved with it so much, except that we're doing government a bit of a favour — we're taking some people off the unemployment register. There's so many people unemployed in Britain at present that, of the recently graduated students in nearly all full-time UK Masters courses, there are many people who are there on Training Agency grants because they can't get a job. So many people are out of work in a country that's losing much of its industry in front of its eyes. Some big companies are closing down, and many small companies are going bankrupt because of high interest rates and the recession. Full-time students are coming in on Training Agency grants, where the government adds a little bit to the money to the money they would otherwise be paying them on the dole.

PROFESSOR McCALLION

If I've understood the question rightly, it's quite worrying — the change of structure that's going on. Under the old scheme, if this problem had arisen, MAF would have funded it at the Agricultural Engineering Research Institute at Lincoln. Has that linkage gone?

BASIL WALKER

It's a problem that's specific to the way we've structured the funding system in New Zealand. I'd have to say, for a start, that to some extent the Foundation, which is the funding agency, is between a rock and a hard place because it's trying to implement a funding system in a situation of cross-currents, and it's trying to chart a course across the cross-currents and stay alive and not get into too much trouble.

In principle, the Public Good Science Fund can and does fund basic science, strategic science and applied research. In fact, if you look at the figures for 1990-91 (which is the last year we have complete figures for), roughly 10 percent went into basic science, 40 percent into strategic science and 40 percent into applied research, so don't imagine for a minute that there's no applied research funded through the Public Good Science Fund.

But what we've had to contend with up until now has been the dogmatic attitude approach adopted by the Treasury on all of this. They have taken the view very dogmatically that things are either suitable for funding for the government, in which case no one has any possible interest in doing anything with the research, or it should be picked up by industry. And there's no middle ground between the two things — it's either one thing or the other.

Now of course the truth of the matter is that that's completely untrue. There's a huge middle ground — grey territory which is neither one thing nor the other. You can call it near-commercial, or applied research — I don't care what you call it, but there is that enormous middle ground which is terribly important.

Because of the dogmatic attitude adopted by the Treasury, everyone's had to sort of tiptoe round the problem and that, I think, has tempted the Foundation to go in the direction of playing safe by only funding things where they thought they weren't going to get into trouble. What we now have to do is bring all of that out of the closet, bring it out into the open and much more directly address the problem of the interlinking between industry funding and Public Good Science funding of research. And that's one of the things we hope to do over the coming year.

UNKNOWN : Are you optimistic?

BASIL WALKER

You've got to be optimistic in the job I do. Yes, I'm moderately optimistic. I'm optimistic in the sense that the current government does have a more pragmatic view of these things than did the previous government, so they're not inclined to be as dogmatic as the Treasury in this kind of area.

TERRY HEILER

But Treasury don't scrutinize the results of the Foundation's allocations, in terms of project by project, do they?

BASIL WALKER : No, they don't.

TERRY HEILER : So is it a matter of removing the fear of the Foundation?

BASIL WALKER : Yes.

JOHN MANNING

We have to respond to the Audit Office auditing us and getting us to explain why grants were given and why priorities were set on different grants, and that's why the forms that you put in are so important.

BASIL WALKER : Are you talking about TBG grants or FRST allocations?

JOHN MANNING : I'm talking about all of them.

BASIL WALKER : Well, FRST allocations are not grants, they're purchases of products.

JOHN MANNING : Okay, so TBG is a purchase of products too.

TERRY HEILER : I wouldn't imagine that would be a problem with audit, would it?

JOHN MANNING

The audit trail has to be there. There has to be an audit trail to show how the Foundation prioritise one application over another. And so what you've written in your application is critical to that, and this is where it comes down to your assessment. You're saying that it may be seen as being appropriable. Well, a lot of that is in the wording of your application.

UNKNOWN

The referee's comments or the feedback coming back from FRST has picked on one or two words to reject the bid. They say because of this that somebody else will pay for it.

BASIL WALKER

Well, that's part of the defensive attitude. They shouldn't be doing that; they should be much more confident in what they're doing. But, as I said, it's not entirely their fault. I think they're contending with a system where the signals don't tend to be very clear at times. I mean they're in a situation where I can talk to them and say one thing, and it's quite likely that the Minister will talk to them and say something slightly different, and someone from Treasury will talk to them and say something different again — and they have to make sense out of all of those slightly conflicting signals.

What we have to do, I think, as I said, is drag all of that out of the closet and put it on the table much more clearly, so that they can then develop some more confidence in doing their own thing. Now there is some risk in that, of course. If you drag things out and put them on the table, everyone can see what's going on. And it is possible, for example, that our colleagues in Treasury might really start to take fright and start to dig in much more strongly than they have done.

They are doing that, for example, with the exercise that we're currently running on long-term science priorities. We have been quite open in that exercise in trying to shift the funding system in particular directions. And we had an extraordinary submission from the Treasury, extraordinary. (It'll be published, so people can see it.) And what they've done is entirely set aside the technical and strategic content of what the Step Panel has done, and they've focused entirely on the philosophical framework within which it's been done. It's almost as though they've retreated back two or three years and they're talking about appropriability. And this is where I start to tear my hair out.

Why on earth is the government starting to impose a strategic framework on science? Shouldn't we just be leaving it to the market to sort it out? Can't we just work on the basis of marginal cost-benefit? All that sort of tripe, and there it is all coming out all over again because we've sort of triggered them into reacting to what we're doing. But I think we're at the stage where we just have to tough that out and say "Well look, it's a more complicated problem than that — you can't just apply a conventional economic solution to it".

DR RICHARD IBBIT (National Institute for Water and Atmospheric Research)

Can I make one point please, in relation to this grey area of government-funded research in industry and the Step Panel's report and one point that they brought out, which was that they suggested that in those outputs where private enterprise wasn't being seen to be contributing enough, the Public Good funding should be cut. Now, that is going to create some appalling signals to people because we've waited for five or six years for business to come in to providing some research money, and all that anybody has said in those five years is "What an appallingly low percentage, in GDP terms, business does contribute". If they don't start soon, they'll find that even what research is done in their broader interests is just going to evaporate. Now, I'm interested in any comment either you've got on that particular comment that's in the STEP report or Professor Wray has on how that will impact on industry.

BASIL WALKER

Let me just make a couple of quick comments then I'll pass the ball. I think the signal that was given was meant to be the positive signal, rather than the negative signal. And the positive signal was that the government should not get caught in the trap of withdrawing funding because the industry is coming to the party. That was actually the most important signal that was being given, and it was a point I was going to pick up on from Professor Wray's speech: that we need to emphasise the fact that this should be a partnership where the industry is putting money in to deal with the applied and short-term end of the spectrum. The government should be prepared to put money in to support the strategic and basic end of the spectrum — and that's the single most important message that's been given.

The other point that was made very strongly was that we're setting priorities on a five-year horizon, and a very clear signal coming through in the Report is that all we're doing is saying - that's where we'd like to be in five years time. Having decided that's where we want to be, what we have to do is sit down — and that means the Foundation, the government, the industry, the research agencies — and figure out how we're going to get there. And a part of the figuring out process is to look at how the industry can better provide its contribution.

For example, in the agricultural area, where there is likely to be a cut, I think as a part of the whole solution we have to address the problem of why the farming community isn't providing a better contribution in some areas, and what the structural difficulties are in overcoming that. Now we know already from what we've done what one of the structural difficulties is — it's the Commodity Levies Act and the difficulty that the government is having in implementing that. (And we know quite specifically what the problem is in that area, actually.) But that's got to be a part of the solution.

We've got to get away from the situation of regarding each of these things as separate pieces that can be put in different pigeonholes and treated differently. At the end of the day it's a complete picture — you've got to look at it holistically. You cannot deal with the government funding end of the problem without simultaneously looking at the industry end of the problem.

Now the real problem we have with the Public Good Science Fund isn't the level of the Public Good Science Fund, it's the low level of industry funding in research in New

Zealand — and I keep coming back to that time and time again as the most fundamental problem we've got at the moment.

PROFESSOR WRAY

But how do you answer what industry's always said to me when I talk this way about industry paying? They say: "Look, Gordon, we already pay. We are the ones who provide the money and we're having such a job keeping solvent at present, our problem is are we going to exist in a month's time? How can we put long-term money into universities when we're already paying our Corporation Tax and we have done for umpteen years, for the good years. And now we're having a bad time." And, of course, the government have no money either. How do you answer the industry who comes up with that sort of talk, because they regularly do it to me? They've said "If you knew the problems we have in just keeping alive, just keeping going, never mind advancing — how can we put that sort of money in?" That's what they've told me.

JOHN MANNING

The answer in New Zealand may be because our major corporations pay very little tax. Less than 20 percent of the tax take is from corporations.

BASIL WALKER

It comes back to the culture problem, doesn't it. If you have industries that are saying that, then you really do have a cultural problem with those industries and we have the same problem here. In some sectors there isn't a problem, even though they've had hard times like everyone else. In other sectors there's a major problem, and you really have to tackle it in a long-term sense. You can't just go along this year and say "How about it?" and hope to solve the problem, you've really got to think in a five- to ten-year time frame.

PROFESSOR WRAY

Well you see, the Government's always believed in what they call the Rothschild Principle. Lord Rothschild headed a think-tank in the Edward Heath government. Out of it came the Rothschild Report and that was the customer-contractor principle — that industry would pay half and government would pay half in future on things like this. And, of course, every government — Labour governments as well as Conservative governments — have always referred university researchers to the Rothschild findings. The Callaghan government, the Wilson government, both of them Labour governments, adhered to it as well as the Thatcher Conservative government, and so there's always been this idea of 50 percent industry, 50 percent government funding. But usually, the government's given way when industry says: "We'll put our 50 percent in largely in kind, providing the people and the facilities and so on, if you'll provide the real money" — and they've got away with it that way.

Unfortunately most people weren't here to hear my other lectures at the University of Canterbury, when, I talked about how we in the Mechanical Engineering Department had started the Loughborough Teaching Contract — not a teaching company, a teaching contract based on the principle of the Finniston Report (1980) that we would actually do lab work in industry. Our students would go in and tackle real problems in industry on the shop floor.

Some ten years ago we went down to London to the Department of Trade and Industry and the 'Sir Humphrey' of the day said "Go and find 12 disciples." (I thought: I wonder who he thinks I am.) We went and got our 12 disciples — big companies, really big companies: Ford, Austin-Rover, British Petroleum, Metal Box, British Aerospace, GEC, etc. — got them all going down to Whitehall to meet him, and he was surprised to meet real industrialists (and they were all top people in industry). One was the Vice-Chairman of Iveco-Ford, and he became the first chairman of the teaching contract; and another was the Chief Engineer of British Petroleum (300 companies).

This principal civil servant, said to the assembled engineers from industry, "Well look, you're going to have to pay your way on this. You're going to have the customer contractor principle not just in kind — I want a subscription from you. I want you to say you're going to put your money where your mouth is."

And so it was decided that they should each pay a £750 per annum subscription, as well as putting in their industrial staff to tutor the students (after the students had familiarised themselves with the real industrial problems in the company). They would also be paying the expenses of their people coming to Loughborough, tutoring the students on the project and all the rest; in other words putting their time and facilities into it.

Actually one company, a very famous company, turned Judas Iscariot — you know, the disciple that ratted on the situation— and they said, "No, there's no way we're going to pay. On principle we're not going to pay. We're putting our staff effort into this and we're not going to pay the damned extra £750 a year." So industry doesn't always view things the way you'd expect them to. Yet smaller companies paid up — some small companies you've probably never heard of had paid their £750 a year and got a lot out of it. So sometimes you've got to look elsewhere than the big companies. But so many of our smaller companies are having a pretty rough time in the present recession.

DAVID BARNARD (Cement & Concrete Assn)

We are, shall we say, a successful research association, so I'm interested in this question of the government linkages in industry because I think that, in all the changes that have taken place with the FRST funding, research associations which were quite an effective link between the industry and the government — I think our position has been very significantly eroded. I can speak as a Director of the Concrete Research Association, which was our former name, and just to confirm some other comments that have been made about industry funding and the relationship to the government. As government funding reduces, so my industry funding reduces. I, as a director, have a grave problem as soon as the government says "No, we're going to reduce the funding", my masters want to reduce the funding.

Now I have lived with the situation of presenting different schemes, and I'm interested to hear that you are going to revisit this grey area, because we did try for a while and there was a period of time where we would put up front that only 20 percent of a project was public good and 80 percent ours (and I know it's difficult to assess those things, but we honestly tried to assess them). Now I can tell you absolutely straight from the shoulder: if I hadn't got the 20 percent government funding that project would not have gone ahead — in other words, I could not get my industry supporter to proceed — and so there is a real problem in trying to, in fact, get this level of funding.

We understand the difficulties that the Foundation is facing, but as a small agency we're also having some difficulty in coming to terms with what we felt the previous research association was doing. Our Board was structured with four industry representatives, and three from the government, so the government representatives had quite a firm audit control over the monies that were being provided to us as an association — that scheme of things has gone by the board.

As an industry agent we're quite relaxed about contracting work to universities; in other words we in effect become an 'industry broker'. And whether we do the work ourselves (because we've only got limited resources), or whether we contract it out to universities — all those options were open, but now we're lost in a vast sea of the present government funding system and we're having difficulty in coming to terms with it.

Our funding's been drastically cut. You can tell from the name of our Association — I mean, what applied scientist or what pure scientist is going to give money to concrete, for goodness sake? And yet, we are working in areas which are five or six times more advanced than the existing technology that is out there, that the man in the street thinks about. So we've got a grave problem. We have difficulties in putting that over in trying to make these presentations to the Public Good Research. And I know other people have had the same difficulty: you score a lot of As and a lot of Bs and a lot of Cs and you get one E and the project goes out the window because one referee doesn't actually understand what you're going for.

But I would emphasise that I think the aspect of research associations, whatever the automatic funding arrangements that were made (and they can be adjusted) — at one time they were 50/50, then they went to one-part to two-part — at least you were in a situation of getting some stability. And it is my experience that once the government puts that stability in, the industry will put its money in. The interesting thing is that our Association and the cement industry were contributing at a higher level than the national average as a research association, but that funding has now dropped. I don't know where we are now; we're probably below the national average. So what's happened is that those industries that were putting money in are now putting less money in — and, really, that's got to be addressed very quickly; otherwise a few are going to fall off the edge, quite frankly.

JOHN MANNING

That first example — why are you addressing that solely to government? Surely your industry should keep its contribution up to its original level?

DAVID BARNARD

That's what I'm telling you. This is the difficulty that as an engineer, an engineer/manager in the middle of all this scene, I try to make that as a submission. I can't get them to do that; they won't do that. If they see the government pulling away, they pull away — that's the problem.

JOHN MANNING : It's that pre-development gap.

DAVID BARNARD

Yes, even if the government, in our case, had not backed down at all we would've stood a fair chance of holding our industry research investment at that level — but the government has backed down. Okay, because of the size of the cake and all the rest of it, we have to take our chances, but when that takes place the industry says "Hey, hey, hey - we're not going to fund", and they immediately reduce their level. So we as an organisation (admittedly we're owned by the industry), we as an organisation effectively take a double cut, and I know many industries are doing exactly the same thing and certainly that's what's happened in our industry.

And as managers, there's very little we can do about it because we're just caught up in the cross-currents as has been described. It's extremely difficult as a small organisation to fight against those sorts of situations.

TERRY HEILER

It seems to be that those comments are about risk-sharing, and what tends to happen is that if you're in an R&D activity there's an element of risk involved — technological and market downstream — and when people are sharing it everybody's reasonably comfortable, but as soon as one of the partners withdraws and says "I don't want to have as much risk as that, I'll reduce my input", the risk then automatically flops onto someone else and you get the sort of response that you're talking about. I believe the mechanisms that we've got for joining up government, industry and R&D providers are too limited to recognise the reality of that risk.

We've done a lot of private contracts with big private corporates here in New Zealand in affairs that have been quite risky, and the solution has been for us to take some of the risk. The client has become much more amenable to proceed with the project the more risk that we've taken away from him. And I think it's reasonable to expect that R&D providers actually take risk. I don't think it's reasonable that an R&D provider gets paid full money for what they do if it's a risky venture. Why should the risk always settle on the hands of the industry or the other party?

I think we can look usefully at a new range of relationships that might even be reflected in policy and in structures and rules that represent the reality of that, because the contractor/customer relationship doesn't do it. And I don't believe, in all of it, the R&D providers should go in and say government should be doing more or industry should be giving more, but don't put any risk on me — I'm just a scientist or an engineer. Why shouldn't you take the risk if you're involved in that affair and, in return, take some of the returns if you win? It sharpens your focus a helluva lot, in my view.

BASIL WALKER

I think Terry's absolutely right and it's reflected in the more strategic approach that we're now promoting, both in our work on priority setting and in the operation of the Foundation. What we're saying, really, is "You can't run science and technology on the basis of an auction; there's more to it than that. You've got to think about the relationships you have with your suppliers, with the end-users in the industry, with the other players in the research game, and put together a whole strategy which really looks at their interests, the kind of resources they have, they capabilities they have, the kind of risks they're running, where they're wanting to go, where you're wanting to go, and put it together into a total package" — and that's the approach that is being very strongly promoted and is really the answer to many of the problems that are being pointed to at the moment.

My own view (and this is now a personal view which I know isn't shared by some of my colleagues) is that at the applied research end of the spectrum there is a very strong case for actually having a rather explicit partnership between the government as funder and private sector funders by saying "Okay, here is an applied research project which is valuable to New Zealand. If we leave it to the industry it won't happen because the benefits are too vague, it's too long-term, there's too much risk associated with it" and so on.

So there is an element of public good in that programme. The government will front up with about 20 percent of the cost that represents that public good provided that the industry fronts up with the other 80 percent, or whatever. Now it seems to me that's the kind of solution we need to start going back to. We're still talking about the research itself; we're not talking about the kind of institutional funding that we had in the past — there's no going back to that — but we can, I think, talk about a much more explicit partnership at that applied research and development edge of the government funding of science.

JOHN BLAKELEY

I'd now like to bring things to a close, but I invite Professor Wray to have the last word, if he'd like.

PROFESSOR WRAY

I think I've said enough last words, but I've found it a very interesting discussion. It's fascinating to find that some of our problems are also your problems. I'm sure we have passed a lot of this **British** 'culture' or philosophy onto you and we're responsible for it, but we're in an economic mess. I think we in Britain are finally starting to see the light, though. I think that at long last there's a recognition that there's no money for anybody if our main wealth creator dies, that is, manufacturing industry (and I mean it in the widest term — all engineering and technology that relates to our basic product making, processes and systems). If that goes to the wall then you can forget all your education, your health services; you become a Third World country, in effect.

And I think we've started to recognise the situation. Even in the Royal Society I find many distinguished scientists agreeing with me. My work has been in textile machinery, researching, developing and designing new machines that are currently working throughout the world — but when I was about to be elected to the Royal Society, I heard through the 'grapevine' that at the very last hurdle somebody said "Do we really want this knitting man in the Royal Society?" Fortunately for me it seems that somebody else spoke up and said "We could do with a few more like him, because he's contributed to the national wealth". After all, that's how the Royal Society gets it money, it's how the whole blinking country gets it money. And it's about time somebody spoke up to get real engineers into the Royal Society, because they're still talking about the first fellows — they were such great men as Hooke and Boyle — an early Secretary was Samuel Pepys — and they've had many other greatly distinguished scientists since — Isaac Newton, Charles Darwin, Albert Einstein, and many more today — but they stopped selecting many engineers after Isambard Kingdom Brunel and George Stephenson really. They've elected a few more engineers in recent years, but I think it's an attitude that persists within the Royal Society and it typifies a problem within our culture.

Unfortunately, the British system being what it is, as soon as money got tight at SERC last year what did they do? The first thing they cut was the Engineering Design Initiative, which they had previously said they believed in — they cut that down because 'who really wants that?' The next thing to be chopped was the ACME (Application of Computers in Manufacturing Engineering) programme. Why? Because they must protect 'big science', astronomy — "We must keep ahead in discovering more about Mars and the other planets because it's so important to the national economy, isn't it?" — and we must maintain research in particle physics, the massive subscription to CERN, and the various SERC physical science labs, they must continue as on-going costs. So the things that have to go are the things that really contribute to the immediate manufacturing prosperity of the country, which pays for all that big science ultimately.

So we've certainly not won the battle yet and I've been a 'whistle-blower' for 30-odd years on the decline of our manufacturing — other people have as well: Sir Monty Finniston and the Trouble-Shooter on BBC TV, the chap who was Chairman of ICI (you've probably seen him on your television), Sir John Harvey-Jones. He kindly wrote to me about what I'd said in my inaugural lecture and commented, "You and I seem to be whistling the same tune — is there anybody listening?"

JOHN BLAKELEY

Well that seems a good note to finish on. I'd like to thank everybody very much for coming to both the lecture and to this very interesting discussion this afternoon. As you've observed, we have recorded it and the Centre for Advanced Engineering proposes to produce a publication resulting from all our efforts today. Thank you very much for coming, and I declare the afternoon closed.